# SCIENCE ABSTRACTS.

## Section A.—PHYSICS.

**APRIL 1917.**

## CONTENTS.

### GENERAL PHYSICS.

PAGE

**277.** Shutter-testing Machine. *A. B. Hitchens & F. B. Gilbert* .................... 121

**278.** Linear Empirical Formulæ. *H. M. Roeser* .................... 122

**279.** Bending Resistance of Steel and Copper Wire. *Lautz* .................... 122

**280.** Impact in Three Dimensions. *M. W. J. Fry* .................... 122

**281.** Waves in an Elastic Plate. *H. Lamb* .................... 123

**282.** Mutual Induction in Masses. *M. Walker & W. W. Stainer* .................... 123

**283.** The Bursting of Bubbles. *A. A. Campbell Swinton & E[velyn] Beale* ...... 124

**284.** Lasting Soap-bubbles. *J. Dewar* .................... 124

**285.** A New Form of Pitot Tube. *A. Hagenbach & K. Gegauff* .................... 124

**286.** Motion of Solids in Revolving Fluids. *G. I. Taylor* .................... 125

**287.** Dynamics of Revolving Fluids. *Rayleigh* .................... 126

**288.** Space-time Manifold of Relativity. *E. B. Wilson & G. N. Lewis* .................... 127

**289.** Theory of Isostasy applied to Oscillations of Sea-level. *W. B. Wright* ...... 128

**290.** Atomic Model. *R. R. Ramsey* .................... 129

**291.** Einstein's Theory of Gravitation. *W. de Sitter* .................... 129

**292.** Distribution of Meteoric Bodies in Solar System. *H. Jeffreys* .................... 130

**293.** Secular Perturbations of Four Inner Planets. *H. Jeffreys* .................... 130

**294.** Irregular Variable RS Camelopardalis. *H. H. Turner* .................... 130

PAGE
295. Spectroscopic Binary *h.* 4 Centauri. *G. F. Paddock* ........ 131
296. Identification of Lines in Spectrum of $\nu_4$ Eridani. *G. F. Paddock* ........ 131
297. Magnitudes and Colours of Stars in Star Clusters. *H. Shapley* ........ 131
298. Series of Silicon Lines in B-type Stars. *F. E. Baxandall* ........ 131

## LIGHT.

299. Direct-reading Precision Refractometer. *G. W. Moffitt* ........ 132
300. Absorption of Solutions of Cobalt Chloride. *E. O. Hulburt, J. F. Hutchinson, & H. C. Jones* ........ 132
301. Sensitiveness of the Eye to varying Degrees of Light ........ 133
302. Influence of Time upon the Latent Image. *H. J. Channon* ........ 133
303. Photography: Plate Speeds. *O. Bloch* ........ 133
304. Identifying Polarised Light reflected from Crystals. *R. D. Weld* ........ 134
305. Modification of Hilger Method for Measuring U.V. Absorption. *H. E. Howe* 134
306. Luminescence of the Iodide of Millon's Base. *H. B. Weiser* ........ 136
307. Wave-length Energy Distribution in X-ray Spectrum. *B. Davis* ........ 136
308. Intensity of X-ray Reflection. *A. H. Compton* ........ 136

## RADIO-ACTIVITY.

309. Scattering of $\alpha$-Particles by Gases. *R. R. Sahni* ........ 137
310. Atomic Weight of "Thorium Lead." *F. Soddy* ........ 137

## HEAT.

311. Limits of Inflammability of Gaseous Mixtures. *W. M. Thornton* ........ 138
312. Relation of Oxygen to Heat of Combustion. *W. M. Thornton* ........ 138
313. Thermodynamics and Gravitation. *G. W. Todd, J. Larmor, E. H. Barton* 140
314. Thermodynamics of the "Throttling Process." *L. Schames & R. Plank* ... 141
315. Radiation. *R. H. Kent* ........ 141
316. Energy, Equipartition, and Radiation. *W. F. G. Swann* ........ 142

## ELECTRICITY AND MAGNETISM.

317. Unipolar Induction: Existence of the Ether. *E. H. Kennard* ........ 144
318. Electromagnetic Wave Propagation in Wires. *H. Saegusa* ........ 144
319. Energy in the Electromagnetic Field. *E. A. Biedermann & G. H. Livens* 144
320. Reciprocity of Electric and Magnetic Actions. *J. B. Pomey* ........ 145
321. Analogies between Mechanical and Electrical Phenomena. *J. B. Pomey* 146
322. The Electromagnetic System of Units. *E. Brylinski* ........ 146
323. Effect of Magnetic Field on Recombination of Ions. *G. E. M. Jauncey* ... 146
324. Light produced by the Recombination of Ions. *C. D. Child* ........ 147

PAGE
325. Positive Ionisation from Hot Salts. *A. T. Waterman* ..... 148
326. Ionisation Potential of Helium. *C. B. Bazzoni* ..... 149
327. Luminous Efficiency of Electric Arc. *E. Karrer* ..... 150
328. Discharge Images on Photographic Plates. *K. Hansen* ..... 150
329. Effect of Moisture on Electric Wave Paths. *F. Schwers* ..... 150
330. Oscillating Arcs in Ether. *A. Rönnholm* ..... 150
331. Lubrication of Resistance-box Plugs. *J. J. Manley* ..... 151
332. Relation between Tension and Magnetic Permeability. *J. T. Rood* ..... 152
333. Reversible Magnetic Permeability. *W. Kaufmann* ..... 152
334. Influence of Iron Minerals on Magnetic Perturbation. *V. Carlheim-Gyllensköld* ..... 152
335. Remarks upon Pastilles. *L. A. Levy & H. J. Stenning* ..... 153
336. Production of Continuous High-tension Currents. *O. M. Corbino & G. C. Trabacchi* ..... 153

## CHEMICAL PHYSICS AND ELECTRO-CHEMISTRY.

337. General Twin Screws of the Atoms. *A. van den Broek* ..... 154
338. Notes on Pearlite. *H. M. Howe & A. G. Levy* ..... 154
339. Some Properties of Ingots. *A. W. & H. Brearley* ..... 154
340. Merits of various Agents for Deoxidation of Steel. *H. M. Boylston* ..... 155
341. Metallurgy of Cadmium. *F. Juretzka* ..... 155
342. Influence of Elements on Properties of Steel. *J. E. Stead* ..... 155
343. Polymorphic Changes under Pressure. *P. W. Bridgman* ..... 156
344. Velocity of Polymorphic Changes between Solids. *P. W. Bridgman* ..... 157
345. Polymorphism at High Pressure. *P. W. Bridgman* ..... 158
346. Impact-ionisation of Gases by Heat Motion. *F. v. Hauer* ..... 160
347. Counter E.M.F. in the Aluminium Rectifier. *A. L. Fitch* ..... 160

# AUTHORS' INDEX

Barton, E. H., 313.
Baxandall, F. E., 298.
Bazzoni, C. B., 326.
Beale, E[velyn], 283.
Biedermann, E. A., 319.
Bloch, O., 303.
Boylston, H. M., 340.
Brearley, A. W., 339.
Brearley, H., 339.
Bridgman, P. W., 343, 344, 345.
van den Broek, A., 337.
Brylinski, E., 322.
Campbell-Swinton, A. A., 283.
Carlheim-Gyllensköld, V., 334.
Channon, H. J., 302.
Child, C. D., 324.
Compton, A. H., 308.
Corbino, O. M., 336.
Davis, B., 307.
Dewar, J., 284.
Fitch, A. L., 347.
Fry, M. W. J., 280.
Gegauff, K., 285.
Gilbert, F. B., 277.
Gyllensköld, Carlheim-, V., 334.
Hansen, K., 328.
v. Hauer, F., 346.
Howe, H. E., 305.
Howe, H. M., 338.
Hagenbach, A., 285.
Hitchins, A. B., 277.
Hulburt, E. O., 300.
Hutchinson, J. F., 300.
Jauncey, G. E. M., 323.
Jeffreys, H., 292, 293.
Jones, H. C., 300.
Juretzka, F., 341.
Karrer, E., 327.
Kaufmann, W., 333.
Kennard, E. H., 317.
Kent, R. H., 315.
Lamb, H., 281.
Larmor, J., 313.
Lautz, 279.
Levy, A. G., 338.
Levy, L. A., 335.
Lewis, G. N., 288.
Livens, G. H., 319.
Manley, J. J., 331.
Moffitt, G. W., 299.
Paddock, G. F., 295, 296.
Plank, R., 314.
Pomey, J. B., 320, 321.
Ramsey, R. R., 290.
Rayleigh, 287.
Roeser, H. M., 278.
Rönnholm, A., 330.
Rood, J. T., 332.
Saegusa, H., 318.
Sahni, R. R., 309.
Schames, L., 314.
Schwers, F., 329.
Shapley, H., 297.
de Sitter, W., 291.
Soddy, F., 310.
Stainer, W. W., 282.
Stead, J. E., 342.
Stenning, H. J., 335.
Swann, W. F. G., 316.
Swinton, A. A. Campbell, 283.
Taylor, G. I., 286.
Thornton, W. M., 311, 312.
Todd, G. W., 313.
Trabacchi, G. C., 336.
Turner, H. H., 294.
Walker, M., 282.
Waterman, A. T., 325.
Weiser, H. B., 306.
Weld, R. D., 304.
Wilson, E. B., 288.
Wright, W. B., 289.

# SCIENCE ABSTRACTS.

## Section A.—PHYSICS.

---

**APRIL 1917.**

---

## GENERAL PHYSICS.

**277.** *A Shutter-testing Machine.* **A. B. Hitchins** and **F. B. Gilbert.** (Frank. Inst., J. 183. pp. 73–78, Jan., 1917. Phot. J. 57. pp. 64–69; Disc., 69–72, Feb., 1917.)—The want of an instrument of precision for testing the speed and efficiency of shutters has long been felt. Up to the present the machines of Abney and of the National Physical Laboratory have been the finest, but they have failed in one or more of the requirements—precision, simplicity of operation, and durability of construction. In the design of the machine here described these three qualities have been kept in view, and it is claimed that the work has brought forth an instrument both of laboratory precision and commercial utility. Illustrations of the apparatus are given. It consists essentially of a revolving drum mounted on a shaft between a powerful high-speed motor and a Veeder precision tachometer. The speed of the drum may be varied by altering the position of the brushes, but its fine regulation is achieved by a brake acting on the shaft. The accuracy of the tachometer is 1 %, which, with the speed generally used (1250 r.p.m.), only produces an error of 1/5000 sec. in the measurement of a shutter speed of 1/50 sec. The shutter to be tested is held in a universal iris directly in front of a narrow horizontal slit. By means of an arc and a pair of condensers this slit is illuminated by a very powerful spot of light, while its image is brought to focus on the drum by a lens. Thus on exposure there is produced on the strip of film affixed to the revolving drum a band, the length of which at a given r.p.m. determines the speed of the shutter. To make this band self-recording and avoid the tedium of many measurements it is split up into a series of lines by a sector wheel which revolves in front of the drum. The wheel contains 96 slots and, by gearing to the main shaft, is made to rotate at precisely the same speed as the drum; the series of lines in the image, being due to the interruptions of the sector wheel, have a definite time value. At 1250 r.p.m. each one of the lines then represents 1/2000 sec., so that in order to estimate the speed of the shutter it is only necessary to count these. Special arrangements are described for use with shutter exposures greater than 1/50 sec. It is proposed in the near future to make a study of the influence of the various types and number of shutter-leaves upon the efficiency and illuminating power of the shutter. The various driving mechanisms will be studied with a view to finding the most satisfactory method of actuating the shutter. A. E. G.

**278.** *Linear Empirical Formulæ.* **H. M. Roeser.** (Phys. Rev. 9. pp. 80–82, Jan., 1917.)—A great number of cases occur in physics where a straight line suffices to represent a relation between two quantities over a limited region well within the errors of observation. In such cases the data may be submitted to computation and the constants of the "most probable" line evaluated by the method of least squares. Such a line is the best that can be obtained by any means to represent the data. Many times, however, experimenters feel that on account of the accuracy of their data, or on account of their ability to locate a line by eye, the amount of computation involved in a least-square solution is unjustified. Hence a stretched thread or transparent straightedge is moved about among the points until a position is found that seems best to satisfy the relation between the variables. The criterion usually adopted for location is that the sum of the deviations from the line of the points above should be equal to that of the points below. In the latter method it is evident that a point, fixed in the distribution, through which it is known that the best representative line must pass, and about which the straightedge might be rotated until the best location was found, would be of great practical value. The present paper shows how, by a simple calculation, one point on the most probable line may be rigorously determined in any assumed linear distribution whatever. Let $x_1, y_1$; $x_2, y_2$; ... $x_n, y_n$, be $n$ observations on two quantities $x$ and $y$ which vary according to the relation $y = a + bx$. Let $x_m$, $y_m$ be the mean values of the observed values of $x$ and $y$ respectively. Then it is proved that the line that would be given by a least-square solution for the constants $a$ and $b$ passes through the point $(x_m, y_m)$. This point can then be used to locate the line. A. W.

**279.** *Influence of Temperature on the Bending Resistance of Mild-steel and Copper Wires.* **Lautz.** (Zeits. Vereines Deutsch. Ing. 60. pp. 785–788, Sept. 23, 1916.)—An apparatus has been designed in which it is possible to effect the alternate bending of wires through an angle of 180° while the specimen is heated at temperatures up to 320° C. in an oil bath. The results of a large number of tests show that the resistance of iron wires to fracture by alternate bending remains fairly constant up to 120° C. Between 120° and 220° C. the resistance increases rapidly, and above the latter temperature falls very abruptly. The max. values are about double those observed at ordinary temperatures. In annealed wires the maximum is very pronounced, but it is nothing like so sharp in unannealed wires; further, it occurs at about 10 or 20 deg. higher in the unannealed samples. Contrary to expectations, copper broke quicker than iron at ordinary temperatures; the number of alternations rose continuously with the temperature. Bending round a sharp edge gives more reliable results than bending round a radius. The work is to be continued so as to determine the effect of variation in composition, and so on. F. C. A. H. L.

**280.** *Impact in Three Dimensions.* **M. W. J. Fry.** (Roy. Irish Acad., Proc. 33. pp. 75–93, Feb., 1917.)—The problem of impact in three dimensions is incompletely discussed by Routh in his standard treatise on

"Elementary Rigid Dynamics" (7th ed., 1905). He does not show how the initial stage of the impact depends on the roots of a certain equation $F(\theta) = 0$; nor how generally the representative point gets on to the line of no sliding; nor that when sliding ceases and rolling is impossible the motion of the representative point is along a line determined by one particular root of $F(\theta) = 0$. Also, the solution he gives of impact between perfectly rough bodies is not correct, as it may involve the physical absurdity of supposing the impulsive normal reaction to be negative.

These points and others are discussed in this paper, and it is shown that the course of the impact under the most general conditions in three dimensions can be minutely traced, and lastly the correct solution of the problem is given when the coefficient of friction is supposed to be very great.

E. H. B.

281. *Waves in an Elastic Plate.* **H. Lamb.** (Roy. Soc., Proc. 93. pp. 114–128, March 1, 1917.)—The problem of two-dimensional waves in a thin plate has been treated by Rayleigh ["Sci. Papers," 3. p. 249] and the author [Lond. Math. Soc., Proc. 20. p. 225] for wave-lengths great in comparison with the thickness of the plate. But a further examination of the two-dimensional problem is desirable, both as a contribution to elastic theory and a step towards its application to the investigation of the various types of vibration in a solid, none of whose dimensions is regarded as small, in which very little progress has yet been effected. Moreover, modern seismology has suggested various questions relating to waves in an elastic stratum imagined as resting on matter of different elasticity and density; and the discovery of a practical solution of the comparatively simple problem of the present paper would appear to be an almost necessary preliminary to the fruitful discussion of such problems. The results obtained appear fully to justify the author's claim of giving a fairly comprehensive view of the more important vibrations of an infinite plate, together with indications as to the character of the higher modes, which are of less interest. The most interesting feature of the paper is the author's treatment of the "period-equation," equivalent to Rayleigh's equation to determine the period of waves on the surface of an elastic solid ["Sci. Papers," 2. p. 441]. This equation may be regarded as one to determine the periods of the various modes corresponding to any given wave-length; but from this point of view it is, mathematically, very intractable. But when regarded as an equation to determine the wave-lengths corresponding to a given wave-velocity the author finds that it becomes tractable, and forms the key to his successful treatment of the problem. It is pointed out that Fourier's well-known calculation of the effect of an arbitrary initial disturbance in an infinitely long bar is physically defective in that it rests on the assumption that a certain formula, here shown to be valid for long waves only, is valid for all wave-lengths.

G. W. DE T.

282. *Mutual Induction in Masses.* **M. Walker** and **W. W. Stainer.** (Phil. Mag. 32. pp. 592–600, Dec., 1916. Abstract of paper read before the British Assoc., 1915.)—An inquiry into the possible existence of an effect between masses analogous to the mutual induction between electric circuits. A steel flywheel 56 cm. in diam. and 11 cm. thick was mounted on a vertical shaft and driven by an electric motor. In close juxtaposition with the disc, but separated from it by a series of screens, was placed a porcelain disc 51 cm. in diam. and weighing about 10 kg. This disc was suspended by a

bifilar suspension by round steel wires of 0·025 cm. diam. and 21 m. length, the distance between the bifilars being 0·15 cm. The torsional control was only 28 dyne-cm. per radian deflection, and the natural period of swing of the disc was 2460 secs. A mirror and telescope enabled deflections of 1/12000 of a radian to be estimated. The experiment consisted in quickly accelerating the flywheel, maintaining its speed constant for half the natural period of swing of the disc, stopping it and accelerating it rapidly in the opposite direction. As the time taken to reverse the flywheel was only 1¾ mins. (small compared to the natural period of the disc), the action of the flywheel, if any, on the disc was of the nature of a series of impulses such as to induce resonance in it. The calculations show that the change in the angular momentum of the disc bore to the total change in the angular momentum of the flywheel a ratio that was certainly less than $5 \times 10^{-10}$. The slight observed disturbance of the swing of the disc was found to get gradually out of phase with the impulses of the flywheel, and were therefore due to some cause in phase with the velocity of the flywheel and not in phase with the acceleration, which was the effect looked for. A. J. M.

283. *The Bursting of Bubbles.* **A. A. Campbell Swinton** and **E[velyn] Beale.** (Nature, 98. p. 469, Feb. 15, 1917.)—The authors describe a neat method of making visible the way in which the gaseous vortices are produced when bubbles burst at the surface of a liquid. The method consists in creating bubbles by sparking with a Ruhmkorff coil between two wires beneath the surface of some resin oil and thus gasifying the latter. As the bubbles are full of smoke, when they burst the vortex effect is clearly indicated by the formation of the well-known smoke-rings. The size of the bubbles and of the rings depends on the viscosity of the oil, greater viscosity causing bubbles and rings to become larger. This can be shown by warming the oil.

A. B. W.

284. *Lasting Soap-bubbles.* **J. Dewar.** (Engineering, 103. p. 109, Feb. 2, 1917. Abstract of Discourse delivered at the Roy. Inst., Jan., 1917.)—If soap-bubbles, intended to be of long duration are blown in air, the air should be free from dust. Ordinary London air contains about 100,000 particles of organic and inorganic matter per cm.$^3$. As regards the soap solution the author prefers the purest oleic acid (tested by the iodine number) and ammonium soap (not potassium or sodium). The bubbles are blown in purified air by opening a stop-cock in the air-supply tube. The air used for blowing is filtered through cotton-wool. To make the bubbles last the sac of liquid must be removed from its bottom by suction through tubes applied from outside. Some of the bubbles exhibited were nearly half a metre in diam. and were blown in glass vessels containing pure air at atmospheric pressure. Some water was always kept in the bottom of the containing vessel. A bubble 20 cm. in diam. had held out 95 days, smaller bubbles nearly a year. A uniform temperature of about 10° C. favours longevity.

E. H. B.

285. *A New Form of Pitot Tube.* **A. Hagenbach** and **K. Gegauff.** (Phys. Zeits. 18. pp. 21–30, Jan. 15, 1917.)—Describes an exploration of the space surrounding a circular plate in a stream of air, the direction of the stream-lines, and the velocity and static pressure of the air being found by means of a new form of gauge. This consists of a small tube of 1·6 mm. outside and 1 mm. inside diam. closed at one end and pierced at the side

with a small hole. The open end of the tube is connected with a pressure gauge by means of an indiarubber tube. The closed tube is several cm. long and is placed with the portion containing the opening at the point to be studied, the axis of the tube being perpendicular to the direction of the air stream. The tube is then rotated until the max. pressure excess is obtained. This, by means of a pointer attached to the tube, gives the angle of the stream-line. The tube is then rotated through 44°, first on one side of this direction and then on the other. The mean pressure at these points is the static air pressure, for it has been found by preliminary experiments that, for all air velocities, the null-pressure is shown at an angle of 44° (for the particular tube employed) from the direction of flow, while at 85° the points of minimum (reduced) pressure are found. The results obtained in the case of air flowing at an average speed of about 6·5 m./sec. past a normal circular plate are tabulated in full in the paper, and a map of isobars and stream-lines is also given. J. W. T. W.

**286.** *Motion of Solids in Revolving Fluids.* **G. I. Taylor.** (Roy. Soc., Proc. 93. pp. 99–118, March 1, 1917.)—The problem here treated mathematically is the two-dimensional one of the motion of an infinite cylindrical body in a liquid rotating uniformly about an axis parallel to the generating lines of the cylinder. The stream-lines and the reaction between the solid and the fluid are determined, and experiments are described in which the mathematical results are shown to be accurately verified. It is this accurate verification of hydrodynamical theory by the observed behaviour of real solids and fluids which constitutes the special interest of the paper. The theorem thus demonstrated both theoretically and experimentally is that if the cylinder be of the same density as the fluid, then its motion along a path under the action of any assigned external forcive such that the direction of the generators remains constant, is unaffected by a uniform rotation of the whole system including the external forcive. The theorem is true only for two-dimensional motion. In the case of a finite cylinder, for instance, it seems almost obvious that the pressures due to rotation must fall off towards the ends. It is natural, therefore, to suppose that the reaction of the fluid would be insufficient to hold a finite cylinder in its path when the whole system is rotated. The general motion of a sphere in a rotating liquid presents considerable mathematical difficulties, but the initial motion has recently been investigated by J. Proudman [see Abs. 977 (1916)], and according to his results, a sphere drawn through a rotating fluid by means of a string should not move in the direction of the force applied by the string, since the forces due to fluid pressure were shown to be insufficient to hold it in the path which it would follow if the liquid were at rest. A glass tank capable of rotation at various speeds about a vertical axis was provided with a simple mechanism which, by the winding up of a cotton thread, would tow an immersed body centrally from end to end when the tank was stationary. A spherical glass bulb and a thin-walled brass tube 6 in. × ¾ in. were so weighted, as to fall very slowly through water, that their centres of gravity coincided very nearly with the centres of gravity of the displaced water, and that the tube should remain vertical. The cylinder should then, at all speeds of rotation, follow the central line, whereas the bulb should follow a curved line with its greatest deviation from the straight path at its central portion, the deviation increasing with the speed of rotation. This was found to be the case. Observations were also made of the motion of vortex rings across the rotating tank, and they were found to follow curved paths of the kind to be anticipated theoretically from the gyrostatic condition that the plane of each ring should retain its orientation in space unchanged. The author also investigates mathematically the more general case of the motion of a circular cylinder in a fluid which has steady rotational motion at infinity, but does not necessarily rotate as a whole, and applies the results obtained:—(1) To confirm those previously obtained directly for the special case of the more general problem in which the motion of the fluid is one of uniform rotation; (2) to the case when the motion of the fluid is one of uniform shearing.

G. W. DE T.

**287.** *Dynamics of Revolving Fluids.* **Rayleigh.** (Roy. Soc., Proc. 93. pp. 148–154, March 1, 1917.)—Meteorology depends ultimately so greatly on the mechanics of revolving fluids that the clear formulation of such simple conclusions as are within reach may be expected to guide the judgment when exact analysis seems unpracticable. Aitken's recent paper on "The Dynamics of Cyclones and Anticyclones" is taken as the starting-point of the present inquiry, although the present author dissents in some respects from Aitken's views. The condition of symmetry round an axis is here imposed throughout, so that the fundamental equations are most appropriately expressed in terms of cylindrical coordinates $r, \theta, z$, the velocities $u, v, w$, being measured in the directions in which these increase. It is then shown that $(rv)$ may be considered to move with the liquid, in accordance with Kelvin's general theorem respecting "circulation," provided that where V is the potential of extraneous forces, $P \equiv \int dp/\rho - V$, be independent of $\theta$, which will be the case if $\rho$ be constant or a known function of $p$, and P be single-valued. The motion $u, w$, will then be the same as for $v = 0$, provided we introduce a force $v^2/r$ along $r$. Case $u = w = 0$.—Let gravity act parallel to $z$ (measured downwards) on a gas following Boyle's law. Then at a constant level $p$ diminishes inwards. But the resulting rarefaction will not cause ascent, inflow of the heavier part outside being prevented by the centrifugal force. The equilibrium of fluid revolving one way round in cylindrical layers between coaxial cylindrical walls will be stable only if the circulation increases with $r$, and neutral for the circulation constant. With a viscous fluid the stability will be unimpaired by rotation of the outer cylinder, but destroyed by rotation of the inner one. This does not conflict with Kelvin's condition of minimum energy that vorticity must increase outwards ("Coll. Papers," 4. p. 175), for he supposed operations on the boundary changing the moment of momentum, which is here constant. On the other hand, he maintains the strictly two-dimensional character of the admissible variations. But the passage from one two-dimensional state to another may be effected by variations which are not two-dimensional. Of course transition from unstable to permanent stable equilibrium is impossible without dissipative forces, as in the case of a heterogeneous liquid under gravity. But ordinary viscosity does not meet the requirements here considered, as it would interfere with the constancy of circulation. For purely theoretical purposes, however, there is no inconsistency in supposing the $u, w$, motion resisted while the $v$ motion is unresisted. Case $u = f(r,t)$, $w = 0$ or finite constant.—Then P is independent of $z$, and the pressure is determined by the equation $du/dt + u\,du/dr = -v^2/r - P\,dP/dr$. For an incompressible liquid $r$ is determined by the equation of continuity $ur = \phi(t)$, and wheu $u$ and the initial conditions are known, $v$ follows. The motion, now two-dimensional, is conveniently expressed in terms of the vorticity, which moves with the fluid, and the stream function. For the former initially, and therefore permanently, constant throughout the fluid, the appropriate solution shows that if centrally the motion be one of pure rotation, as of a solid, the outer wall will close in, and, in addition to the pure rotation, the fluid will acquire the motion of a simple vortex of intensity increasing as the radius of the outer wall diminishes. If the fluid be contained between two coaxial cylinders, both walls must move inwards together, and the process will end when the inner wall reaches the axis. But the inner wall, or both, may be dispensed with, and the inflow at $r = r_1$ be supposed removed. It will then remain true that, if it thus pass at a constant pressure, the pressure at $r = r_2$ must continually increase. If a limiting pressure be reached, the inward flow must cease. Calculation of any more general case does not seem practicable, but it can be seen that when the $u$, $w$ motion is slow relatively to the $v$ motion a kind of equilibrium theory is approximately applicable, much as when the slow motion under gravity of a variably dense liquid retains approximately its horizontal stratification; *e.g.* oil standing over water can be syphoned off without much disturbing the water. When the density varies continuously the syphon would tend to draw from the horizontal stratum at which it opens. Or if liquid escapes slowly through an aperture in the bottom of the containing vessel, only the lower strata are disturbed. So when revolving fluid is drawn off near a point on the rotation axis, the surfaces of constant circulation tend to remain cylindrical, and the more decidedly the faster the rotation. The escaping liquid is drawn always from along the axis, and not symmetrically in all directions, as when there is no rotation. The stability of fluid motion in cylindrical strata requires only an increase outwards in the square of the circulation. But if the latter be in both directions, this involves discontinuities, and for stability rigid symmetry with respect to the axis. Without this limitation the motion will be unstable, so that stability really requires circulation in one direction only. The general question of two-dimensional motion of liquids between fixed coaxial cylindrical walls has been treated by the author in a former paper ("Sci. Papers," 1. p. 487), and it may be shown, as on the lines of the demonstration there given for plane strata, that the motion in cylindrical strata is stable provided that the rotation either continually increases or continually decreases in passing outwards from the axis.

G. W. de T.

288. *Space-time Manifold of Relativity: The Geometric Potential.* **E. B. Wilson.** (Washington Acad. Sci., J. 6. pp. 665–669, Dec. 4, 1916.)—In a former paper by G. N. Lewis and the present author [see Abs. 328 (1913)], it was shown how the potential of a distributed charge could be built up from that of a point charge expressed as the product of the charge and a vector **p**. To find the value of **p** at a point Q of the four-dimensional manifold and due to a curve $\delta$ which is the space-time locus of a moving charge, the first step is to draw the backward singular cone with vertex Q and determine its intersection O with the curve $\delta$; then draw at O the forward unit tangent **w** to the curve, and let the perpendicular from Q to this tangent be **R**. If then $\mathbf{l}$ denotes the vector OQ, the singular vector from the acting point to the point at which the potential is desired, the potential is $\mathbf{p} = 1/\mathbf{R} = -1/\mathbf{l}.\mathbf{w}$, the vector $p$ satisfying the two fundamental conditions $\diamond . \diamond . \mathbf{p} = 0$, and $\diamond \mathbf{p} = 0$, of which the first is the wave equation needed to represent the fact of an electromagnetic disturbance, while the second is the condition usually imposed upon the two auxiliary functions involved in order to complete their determination. The identification of **p**, so defined, as the potential, is justified by the proof, in the previous paper, that, apart from a numerical multiplier,

it is the only possible form for the potential, in that it is the only function of $l$ and $w$, the retarded position and velocity, only, and therefore independent of the acceleration, which satisfies the two fundamental conditions. The authors call it a geometric potential, in that its definition is solely geometrical. They then show that the condition $\Diamond \mathbf{p} = 0$ is superfluous; from which it follows that the only possible choice for the geometrical potential $\mathbf{p}$, dependent only on $\mathbf{l}$ and $\mathbf{w}$, but not on the derivatives of $\mathbf{w}$, and satisfying the wave equation $\Diamond . \Diamond \mathbf{p} = 0$, is $\mathbf{p} = A\mathbf{l}/R$, where $A$ is a constant. And this, from the point of view of relativity, provides a completely rational basis for the theory of the potential and field of the point charge, and through it, by integration, for the theory of continuous distributions of electricity. The potential being found to be homogeneous and of degree zero in $\mathbf{w}$, it follows that $\mathbf{p} = -\mathbf{w}/\mathbf{l}\mathbf{w} = \dot{-}\,\mathbf{u}/\mathbf{l}\mathbf{u}$, where $\mathbf{u}$ is *any* tangent to the curve $\delta$. If now $dq$ be defined by the relation $d\mathbf{r} = \mathbf{u}\,dq$, where $d\mathbf{r}$ is the increment along the curve, a parametric representation of the curve is determined, so that $\mathbf{u} = d\mathbf{r}/dq$, which is analogous to $\mathbf{w} = d\mathbf{r}/ds$, but more general in that it is applicable to curves of zero length. Writing $\mathbf{c}' = d\mathbf{u}/dq$, a second vector $\mathbf{P}$ is obtained, defined by the equation—

$$\mathbf{P} = \Diamond \times \mathbf{p} = -\frac{\mathbf{u}.\mathbf{u}}{(\mathbf{l}.\mathbf{u})^3}\mathbf{l} \times \mathbf{u} + \frac{\mathbf{l} \times [\mathbf{l}.(\mathbf{u} \times \mathbf{c}')]}{(\mathbf{l}.\mathbf{u})^3},$$

which is the geometric field set up by the potential; the first term varies inversely as the square of the interval of $\mathbf{l}$, and the second term inversely as the interval itself. When $\mathbf{u} = \mathbf{w}$ the result reduces to that obtained in the previous paper, but the present form, unlike the former, is applicable to the case of a singular curve, and therefore to the path of a particle of light, and not only to curves that can be described by electrons or material particles. If $\mathbf{u}$ be a singular vector the first term in $\mathbf{P}$ vanishes, since $\mathbf{u}.\mathbf{u} = 0$; from which it follows that in the geometric field of a particle of light that portion which corresponds to Coulomb's law for the field of an ordinary particle vanishes identically. The field $\mathbf{P}$ vanishes entirely unless the particle of light, assumed to be moving with the normal velocity of light in free space, travels in a curved path, so that $\mathbf{c}$ is not parallel to $\mathbf{u}$. G. W. DE T.

**289.** *The Theory of Isostasy as applied to the Quaternary Oscillations of Sea-level.* **W. B. Wright.** (Nature, 98. pp. 499–500, Feb. 22, 1917.)—In view of an important paper published by the Geological Survey of Canada dealing with the application of the theory of isostasy to the quaternary oscillations of sea-level, the present author gives here a short *résumé* of the theory, pointing out to what extent the newly recorded observations tend to place it on a firmer basis. This theory ascribes the raised and tilted shorelines, which are found around the centres of glacial dispersal, to the sinking in of the earth's crust beneath the pressure of the ice-sheets and its subsequent recovery when the ice has melted away. The depression and recovery were greatest at the centres of dispersal, where the ice was thickest, with the consequence that the shore-lines are highest near these centres and descend gradually towards the margins of the glaciated districts. Before they actually reach these margins they pass beneath the present sea-level, so that there are no late glacial raised beaches in the peripheral part of the glaciated districts. The shore-lines which were formed during the retreat of the ice from these areas are all beneath the present sea-level. Now this in connection with all the quaternary ice-sheets is very strong evidence of a general lowering of the ocean-level during the glaciation. Moreover, calculations based on the quantities of water which must have been bound up in these ice-sheets, and so removed from the ocean, seem to indicate that this cause is quite adequate to produce the observed effects. Two factors must therefore be dealt with, in seeking for an explanation of the late glacial changes in the relative level of land and sea, viz. (1) The local isostatic recovery of the earth's crust. (2) The general raising of the level of the ocean due to the melting of the ice-sheets. According as the first or second of these factors predominated, there occurred either emergence or submergence in the isostatically affected areas. This appears to be the explanation of the curious fact established by W. C. Brogger in the Christiania region, that the first change of level after the retreat of the ice was one of submergence, which, at a somewhat later stage of retreat, gave place to emergence. Johnson now brings forward evidence, of a nature similar to that adduced by Brogger, to show that the late glacial changes of sea-level in the Ottawa valley were precisely the same as those established for the Christiania region. He also shows that the tilting of the Great Lakes region was in progress before and during the rise of the sea in the Ottawa valley. There is thus direct proof that a district which was rising relatively to those around it was nevertheless undergoing submergence beneath the level of the sea. Canada has therefore supplied unexpected evidence of the individual existence of isostatic recovery and general rise of sea-level, whereas Norway has up to the present only supplied a measure of the difference of these two motions. H. H. Ho.

**290.** *Atomic Model.* **R. R. Ramsey.** (Phil. Mag. 33. pp. 207–211, Feb., 1917.)—For the Mayer experiment of floating needles, the author substitutes small bicycle-balls floated in mercury. But in the classical Mayer experiment the needles are fixed. There is nothing to suggest how the atom may radiate. The atom is dead. The motion of the atom must be imagined. It is usual to imagine the needles to rotate about the centre with a constant angular velocity. This is contrary to the laws of planetary motion as illustrated in the solar system.

To remedy this lack the author rotates the mercury and thus rotates the balls. By sending a current into the mercury by a middle electrode and taking it out at the four corners of a square tray the mercury rotates in the vertical magnetic field. The various perturbations that may be observed are described and include the imitation of a possible light-radiation, the production of X-rays, photoelectric effect, ionisation produced by hot bodies, $\gamma$-rays caused by $\beta$-rays, etc. E. H. B.

**291.** *Einstein's Theory of Gravitation and its Astronomical Consequences. II.* **W. de Sitter.** (Roy. Astron. Soc., M. N. 77. pp. 155–184, Dec., 1916.)—This second paper [see Abs. 11 (1917)] is chiefly mathematical and contains eleven articles dealing successively with the field of *n* moving bodies, the problem of *n* bodies, lunar theory, motion of lunar perigee and node, field of moving sun and motion of infinitesimal planets in it, gravitational field of the fixed stars, upper limit for total mass of stars, irreality of coordinates, relativity of rotation, origin of inertia, and hypothesis of distant masses. Much of the paper scarcely lends itself to abstraction; the following points may, however, be noted.

The motion of the lunar perigee and node when compared with observation is not decisive either for or against Einstein's theory.

Rotation in its purely kinematical aspect is shown to be relative in the new theory, quite as relative as linear translation. We can transform it away as we can transform away linear translation. But there is a difference. If a linear translation is transformed away by a Lorentz-transformation it is utterly gone, no trace of it remains. Not so in the case of rotation. The transformation which does away with a rotation, at the same time alters the equations of relative motion in a definite manner. This shows that rotation is not a purely kinematical fact, but an essential physical reality. Its amount $\omega$ is a physical constant, proper to the earth, like its mass.

The author has purposely referred only to such methods of ascertaining and measuring $\omega$ which depend exclusively on observations made on the surface of the earth (Foucault's pendulum, gyroscopes, the ellipsoidal figure of the earth), without any reference to celestial bodies. That by all these methods, and also by the apparent daily motion of the stars, we find the same value of $\omega$, is a confirmation of the correctness of the theories by means of which the various phenomena, which are used in the different methods, are explained, especially of the theory of inertia. But all this is entirely independent of the system of coordinates.

Even if Einstein has not explained the origin of inertia and gravitation, his theory represents an enormous progress over the Physics of yesterday. Perceiving the irrelevance of the representation by coordinates in which our science was clothed, he has penetrated to the deeper realities which lay hidden behind it, and not only has he entirely explained the exceptional and universal nature of gravitation by the principle of the identity of gravitation and inertia, but he has laid bare intimate connections between branches of science which up to now were considered as entirely independent of each other, and has thus made an important step towards establishing the unity of Nature. Finally, his theory not only explains all that the old theory of relativity could explain (Michelson's experiments, etc.), but, *without introducing any new hypothesis or empirical constant*, it explains the anomalous motion of the perihelion of Mercury, and it predicts a number of phenomena which have not yet been observed. E. H. B.

292. *Distribution of Meteoric Bodies in Solar System.* **H. Jeffreys.** (Roy. Astron. Soc., M.N. 77. pp. 84–112, Dec., 1916.)—An investigation is made of problems arising when a swarm of small solid bodies, of size comparable with a meteor or smaller, is supposed to move under gravity about a large nucleus. The first type considered is that in which the motion is steady and the swarm is symmetrically distributed about an axis through the central mass. The two cases analysed are the rings of Saturn and the Zodiacal light. A second section is devoted to the motion of meteors in the vicinity of the earth's orbit, and a third to the planetesimal hypothesis of Chamberlain and Moulton. C. P. B.

293. *Secular Perturbations of Four Inner Planets.* **H. Jeffreys.** (Roy. Astron. Soc., M.N. 77. pp. 112–118, Dec., 1916.)—Various investigators have attempted to account for the observed secular variations in the orbits of the inner planets, the principal discrepancies being in the perihelion of Mercury and the node of Venus. A summary is given of this work, and reference made to the partial explanation given by Einstein in the cases of Mercury and Mars [Abs. 858 (1916)]. C. P. B.

294. *Irregular Variable RS Camelopardalis.* **H. H. Turner.** (Roy. Astron. Soc., M.N. 77. pp. 118–124, Dec., 1916.)—Referring to the paper by C. Martin and H. C. Plummer on the variability of this star [Abs. 1112 (1916)],

it is shown that any case of variation, with an approximate average period, however irregularly the variation may be distributed about that period, can be represented by three terms with arguments in arithmetical progression, provided the whole period of observation is short enough. Objection is taken to the use of the term "periodicity" in cases where the coefficient may regularly change sign. In particular, it is contended that the assigned period should be that of the term with largest coefficient; in the case of RS Camelopardalis this should be 82·2 days, instead of 88·7 days as given by Martin and Plummer. C. P. B.

295. *Spectroscopic Binary h. 4 Centauri.* **G. F. Paddock.** (Lick Observatory Bull. 9. [No. 288], pp. 42–47, Jan., 1917.)—This southern star belongs to spectral class B5, the lines of helium being conspicuous and more numerous than lines of other elements. A list of the lines observed between λ3983 and λ4922 is given, and details of the velocities deduced from each of 87 plates taken between 1908 May 4 and 1911 Aug. 6. Special attention has been given to the character of the comparison lines in making the reductions, as in several cases there are lines due to several elements blended together, and the proper identification is somewhat difficult to decide. The period is found to be a little less than 7 days. Definitive elements are given, and the corresponding velocity curves. No certain evidence of any secondary spectrum has hitherto been obtained. Attention is drawn to several calculations of parallax of the star, which appear to be remarkably concordant. C. P. B.

296. *Identification of Lines in Spectrum of $\nu_4$ Eridani.* **G. F. Paddock.** (Lick Observatory Bull. 9. [No. 288], p. 47, Jan., 1917.)—The line at λ4282·7 is now identified as due to enhanced manganese, and that at λ4416·9 due to enhanced iron. The latter is very close to an air line in the spark spectrum. C. P. B.

297. *Magnitudes and Colours of Stars in Star Clusters.* **H. Shapley.** (Mt. Wilson Solar Observatory, Contribs. Nos. 115, 116, 117. Nature, 98. p. 438, Feb. 1, 1917. Abstract.)—From an extensive investigation of 1300 stars of the Hercules cluster it is concluded that the colour-indices show no appreciable effect of selective scattering of light in space, but the apparent increase of redness towards the centre seems to imply an absorption within the cluster itself. Five new variables have been discovered, all of which are probably of the Cepheid type. C. P. B.

298. *Series of Silicon Lines in B-type Stars.* **F. E. Baxandall.** (Observatory, No. 509. pp. 59–60, Jan., 1917.)—In a paper by Henroteau [Abs. 115 (1917)] a series relationship was suggested as existing among the known doublets of the silicon spectrum, but somewhat inaccurate wave-lengths given by Porlezza were used for the calculations. The more accurate values of Hartmann, Frost, and Brown are here employed, leading to different values of the figures. It also seems doubtful if all the doublets mentioned by Henroteau really belong to a single series. C. P. B.

## LIGHT.

299. *Direct-reading Precision Refractometer with uniformly divided Scale.* **G. W. Moffitt.** (Phys. Rev. 8. pp. 668–678, Dec., 1916.)—A point source of light is placed below (preferably at the centre of curvature of) a spherical lens having concentric surfaces. A drop of the liquid whose refractive index $n$ is to be determined is placed upon the lens, and covered by a plane-parallel glass plate in contact with the lens. Above this combination at distance $k$ is placed a converging lens L, of focal length $f$. Let $p$ be the distance above lens L of the image of the source formed by the whole optical system. The problem is to arrange matters so that the length $p$ shall vary directly as the index $n$. On calculating $p$ by the usual formulæ of geometrical optics (neglecting the thickness of the lenses) it will be found that the condition for the resulting expression for $p$ being linear in $n$ and $p$ is $f - k = t/n'$, $t$ and $n'$ being the thickness and index of the plane parallel plate. When this condition is satisfied, the expression for $p$ takes the form $n = (\mathrm{R}/f^2)p + (1 - \mathrm{R}/u - \mathrm{R}/f)$, R being the radius of the concentric lens, and $u$ the distance, from the curved liquid surface, of the image of the source due to the concentric lens. If the source be at the centre of curvature, then R and $u$ are equal. If O and I be the diameters of an object and its image formed by the system, then $\mathrm{I}/\mathrm{O} = f/u$, a constant if the source be fixed. If the converging lens L is strictly achromatic, the adjustment for $k$ is correct for all wave-lengths. With a lens L of the simple uncorrected type, it may be possible to construct an instrument sufficiently achromatised for many cases, and which can be used with white light to determine the mean index. The best position for the stop is either at the principal focus of L, or at L itself. The refractometer resembles an ordinary microscope in appearance. The plane-parallel plate is placed at the lower end of the tube, and the converging lens higher up in the tube at the proper distance. An eyepiece is mounted at the upper end, with rack-and-pinion adjustment for focusing. The focusing tube is provided with a scale, divided in accordance with the above equation. In place of the stage a heating tank is provided, through the centre of which passes a spring-mounted tube carrying an object scale at its lower end, and the lens on which the liquid is placed at its upper end. The spring-mounting lifts the lens into a position easy of access when the microscope is raised. When the converging lens and plane-parallel plate are correctly adjusted, parallel light incident on the lens from above should come to a focus on the lower surface of the plate. If two scales be ruled with divisions in the ratio of $f$ to $u$, one may be used as an eyepiece lateral scale, and the other as an object whose image is formed at the eyepiece. When focusing is complete, image and eyepiece scale will appear to coincide. A trial instrument constructed on the above lines gave index determinations correct to one or two units of the third decimal place. The lens L had focal length 8·5 cm., and aperture stopped down to under 1 cm. The concentric lens had radius 6·0 cm. A scale interval 1·282 cm. corresponded to a change 0·1 in index of liquid. The length of object and image transverse scales was 0·5 cm. The value of $u$ was made equal to $f$, giving unit magnification and shortest tube-length. A. E.

300. *Absorption Coefficient of Solutions of Cobalt Chloride in Water and Alcohols for Monochromatic Radiation.* **E. O. Hulburt, J. F. Hutchinson,**

and **H. C. Jones**. (J. Phys. Chem. 21. pp. 150–164, Feb., 1917.)—Experiments have been made with a grating spectrograph using a monochromatic source of light in order to determine the absorption coefficient and the molecular absorption of solutions of cobalt chloride in water, methyl, ethyl, propyl, iso-butyl and iso-amyl alcohols. The variations of A (absorption coefficient, molecular) with wave-length have been measured and graphed for different concentrations (*c*) and the results are compared in some cases with the previous measurements of Houston. A is found to vary with *c* in all possible ways except that it never increases to a maximum and then diminishes. The authors regard their results as qualitative evidence for the existence of "solvates," but for quantitative purposes they state that the solvate hypothesis must be couched in mathematical terms. C. S. G.

301. *Sensitiveness of the Eye to varying Degrees of Light.* (El. World, 69. pp. 41–43, Jan. 6, 1917.)—A series of diagrams, derived from experiments made by P. G. Nutting in the Eastman Kodak Research Laboratory are given. These illustrate, among other matters, the adaptation of the eye to high and low illumination, and the effect of varying brightness of field on the percentage brightness-change perceptible to the eye. This factor ($B/dB$) increases with increasing brightness up to about 1 millilambert, then more slowly to 100 millilamberts, after which the curve falls again, owing to the effect of glare. Other diagrams illustrate progressive adaptation to white and coloured light. A linear relation is also traced between the brightness of a field and the increase in brightness sufficient to cause glare. From this can be deduced the fact that a light which causes glare in dark surroundings can be viewed with comfort in daylight; and the exact order of brightness liable to cause glare is determined. The absolute glare limit, beyond which adaptation cannot take place, appears to be about 50 lamberts, which is five times as bright as white paper in direct sunlight. Other curves show the action of the pupil aperture in closing to counteract excess of light. J. S. D.

302. *Photography: Influence of Time upon the Latent Image.* **H. J. Channon.** (Phot. J. 57. pp. 72–84; Disc., 84–87, Feb., 1917.)—Describes the development at long intervals of plates originally exposed in 1894 and stored. Clear evidence is obtained of photo-retrogression, but the extent of this varies enormously in plates of different makes; it is most apparent in the weakening of the larger densities unless these are due to very long exposures. More or less general fog develops in the unexposed parts during storage; this depends on the kind of plate. Along with general fog, in most cases, appears a considerable increase of the densities due to the weak light impressions in the neighbourhood of the "Schwellenwert"—analogous to the effect of supplementary light exposure and equivalent to increasing the plate speed. Probably this effect ceases to increase after a certain time and then falls off. Characters of plates—sensitiveness, density capacity—do not alter much with the lapse of many years. Photo-retrogression is not a property of rapid plates as such: the greatest amount of it is in the first interval of time and it progressively diminishes. The action of air on exposed plates is widely different according to the make. A. D.

303. *Photography: Plate Speeds.* **O. Bloch.** (Phot. J. 57. pp. 51–61; Disc., 61–68, Feb., 1917.)—Refers to the plates and developers employed; in the case of bromided developers and for specified exposure conditions there are definite H. and D. speeds for all these plates, but only above certain limiting

values of $\gamma$, which are often high. In the case of non-bromided developers or developers containing only very small amounts of bromide, certain plates (usually those of the more rapidly developing type) appear to possess definite H. and D. speeds for all the values of $\gamma$ generally employed and for specified exposure conditions; in the case of certain types of plate (usually those which develop slowly) the H. and D. speed is higher for the lower values of $\gamma$, and all or many of the points of the plate curve lie on a straight line. During the transitional period these plates possess a definite H. and D. speed for each particular value of $\gamma$ until a limiting point is reached, when the plate curve becomes normal; beyond this point the H. and D. speed is constant for specified exposure conditions. Plates fail in varying degree to obey the reciprocity law, and the H. and D. speed of the plate varies considerably with variations of I and $t$ (I × $t$ being constant), being much lower when the light is feeble and the exposure long. A. D.

304. *Method for Identifying Polarised Light reflected from Small Opaque Crystals.* **R. D. Weld.** (Iowa Acad. Sci., Proc. p. 285, 1916.)—This new method is a modification of one originally used by Voigt for the identification of elliptically polarised light. The light under examination passes first through an arrangement of quartz wedges acting as a Babinet compensator, then through a "rotator" consisting of another pair of quartz wedges cut perpendicular to the axis, one from right-handed, the other from left-handed quartz, and finally through a large Nicol prism. The result is that the field is filled with rows of black spots in regular arrangement; and from the location of these spots with reference to the cross-hairs the exact character of the elliptic vibration can be readily calculated. In the particular application considered, the parallel beam of light reflected from a small metallic crystal is very slender, so that only a small portion of the field is illuminated at once. In order to produce the spot pattern, the analysing apparatus is carried backwards and forwards at right angles to the beam, until the whole field is covered. The pattern then appears clearly on the photographic plate, and measurements are easily made upon it. Some excellent plates have been obtained in this manner from very small crystals of selenium. From such plates it ought to be possible to settle the question whether metallic crystals are doubly refracting. The preliminary results indicate that such is, in fact, the case with selenium. Further results will be published later. A. W.

305. *Modification of the Hilger Sector Photometer Method for measuring Ultra-violet Absorption; and Application to Derivatives of Fluoran.* **H. E. Howe.** (Phys. Rev. 8. pp. 674–688, Dec., 1916.)—The author has found that the photographic plate, the use of which in photometry is usually considered questionable, integrates intermittent exposures in such a way that the comparison of two intensities can be made directly in terms of sector openings, provided that the two exposures produce equal blackening of the film and that the total times from beginning to end of exposure are the same. The aluminium spark under water, described by Henri [Abs. 1818 (1913)], has been improved until it has become a very strong source, easy to control, and fairly constant. The aluminium spark is affected greatly by the action of the spark at the gap in the secondary (which consists of a single layer of annunciator wire wound on a wooden frame). Several sorts of spark-gap were tried. The best form consisted of two zinc discs cast on steel shafts, and mounted so as to rotate with their edges 8 mm. apart. A small amount of tap-water added to the distilled water sufficed to render the

discharge between Al electrodes silent, owing probably to increased conductivity. For plotting absorption curves, Baly and Detsch's method has usually been followed, in which photographs of the spectrum of the source, and of the transmission spectra of layers of different thickness, are taken on the same negative, during the same time of exposure. That method makes no allowance for the absorption of the solvent, and the resulting error changes with the thickness of absorbing layer. With alcohol as solvent the error in the extreme ultra-violet is considerable. There is also difficulty owing to the two parts of the plate to be compared being far apart. The author's apparatus enables the true absorption of the solute to be found. Two beams, (1) and (2), proceed from the source, and each passes through a cell C, a quartz prism P, and a rotating sector S. Both beams then fall on a small biprism, and are so bent that they are focused by the spectrograph as two narrow spectra with a fine dividing line between. $C_1$ contains the absorbing solution, $C_2$ the solvent. $S_1$ has a constant opening of 180°, $S_2$ is variable and has a scale-reading in logarithms of the relative openings of $S_1$ and $S_2$. On the developed negative the points of equal blackening are marked, and the corresponding frequencies read by means of a transparent frequency scale. To locate the points of equal blackening, the negative is laid on an illuminated milk-glass plate, and a paper screen with a small hole in it is moved along the blackened strip until the point of match is found. A dot is then made with a fine pen. The assumptions that may be made in photometry by photographic means have been stated by Hartmann somewhat as follows :—Two beams which produce equal blackening of two areas of the plate may be taken as equal provided (1) the two beams are of the same wave-length ; (2) they act upon near parts of the plate ; (3) they are of constant intensity, or vary together ; (4) they act simultaneously. All these conditions except the fourth are met by the Hilger apparatus. The total time from beginning to end is the same for the two beams. But the beams have unequal intensities, and the effective times during which they act on the plate are unequal, being inversely proportional to the sector openings. Hence it is necessary to determine, for each ratio of sector openings, what relative intensities will produce equal blackenings under the conditions stated. The author finds that the intensities are inversely proportional to the sector openings, though the makers of the apparatus assume no such simple relation. The table below shows three ways in which energy may act upon a photographic plate :—

| Intensity. | Total Time of Exposure. | Manner. | Effective Time. | Blackening. |
|---|---|---|---|---|
| I | $t/n$ | Continuous | $t/n$ | $B_1$ |
| $1/n$ | $t$ | Continuous | $t$ | $B_2$ |
| I | $t$ | Intermittent | $t/n$ | $B_3$ |

The second case may be realised by interposing an absorbing screen transmitting only $1/n$ of the light. The third case is that of a rotating sector with angular opening 360°/$n$. It is known that $B_1$ is greater than $B_2$ (Schwarzschild), and that $B_1$ is greater than $B_3$ (Abney, Phot. Soc., J. 1893–94). Visually $B_2 = B_3$. The author's results show that the photographic plate also integrates the third case of exposure so as to give $B_2 = B_3$. Curves illustrating the process are given for the ultra-violet absorption of fluoran, fluorescein, and derivatives, and a group of related phthaleins. Some results for phthaloximes were compared with those obtained by Pratt by another method, and agree as to the position of greatest absorption, but differ as to which of two isomeric forms absorbs most strongly. The author's curves show that the molecular absorption constant is of the same order of magnitude for solutions of compounds closely related structurally. All the solutions had concentrations between 0·0001-N and 0·0002-N. The curves show also the increasing absorption with increasing mass of the groups substituted for hydrogen in the molecule. A. E.

306. *Luminescence of the Iodide of Millon's Base.* **H. B. Weiser.** (J. Phys. Chem. 21. pp. 37–47, Jan., 1917.)—When heated, the iodide of Millon's base, or Nessler's precipitate, decomposes with formation of ammonia, mercuric iodide, nitrogen, water and mercury. The decomposition occurs without previous melting and, when rapid, emits light and absorbs heat, the light emitted being particularly bright and of a distinct violet colour. A summary is given of the luminescent reactions of mercury and it is shown that (1) the change from mercury to mercurous salt is accompanied by an orange luminescence, (2) that from mercurous salt to mercuric salt by a green luminescence, and (3) that from mercuric salt to mercury by a violet luminescence. It is probable that the luminescence in these cases is due to (1) the reaction $Hg^{\cdot} \longrightarrow$ undissociated mercurous salt, (2) $Hg^{\cdot} \longrightarrow Hg^{\cdot\cdot}$, and (3) $Hg^{\cdot\cdot} \longrightarrow Hg$. T. H. P.

307. *Wave-length Energy Distribution in the Continuous X-ray Spectrum.* **B. Davis.** (Phys. Rev. 9. pp. 64–77, Jan., 1917.)—Referring to the experimental work of Duane and Hunt [Abs. 1419 (1915)] and of Hull [Abs. 380 (1916)] the author attempts to develop a theory of the "white" X-ray spectrum. Two distinct hypotheses are made as to the origin of the radiation: (*a*) a pulse hypothesis, (*b*) a quantum hypothesis. Both hypotheses lead to the result that the energy radiated is proportional to the square of the frequency. Having obtained this general relation the author proceeds to derive an equation for the resultant radiation by *all* the electrons of the kathode stream incident on the target. The mathematical expression is rather complex, but a comparison of experimental and theoretical curves shows that there is a fairly good agreement. An expression is also obtained for the relation between the energy radiated at constant wave-length and the voltage applied to the X-ray tube. The theory indicates that the energy increases rapidly with increasing voltage, but attains a max. value. This maximum was not observed by Duane and Hunt, since their experiments did not extend over a sufficient range of voltage. A. B. W.

308. *Intensity of X-ray Reflection, and the Distribution of Electrons in Atoms.* **A. H. Compton.** (Phys. Rev. 9. pp. 29–57, Jan., 1917.)—The question is dealt with mathematically. In the first part of the paper an expression is derived for the energy of a beam of X-rays of definite wave-length which is reflected from a crystal. The result is in accord with that previously derived by Darwin [Abs. 1262 (1914)], and shows that the intensity of the reflected beam depends not only upon the angle of reflection but also upon the arrangement of the electrons within the atoms of the reflecting crystal. The form of the equation for the energy in the reflected beam is shown to be independent of the degree of perfection of the crystal and of the length of the wave-trains of which the X-rays consist.

It is shown that there is no possible distribution of the electrons which will lead to Bragg's empirical law [see Abs. 876 and 1840 (1914)] for the intensity of reflection; it is found rather that any formula for this intensity must depend not only on the angle of reflection but also upon the wavelength of the incident rays.

It is noted that Bragg's experimental data indicate differences in the reflection from certain crystals that can only arise from differences in the distribution of the electrons in the atoms of which the crystals are composed. Assuming a number of electrons in each crystal equal to the atomic number, and making certain assumptions concerning the arrangement of these atoms in rings, the observed intensities of X-ray spectra are accounted for. The results of the investigation indicate that the electrons are not concentrated within a very small distance from the centre of the atoms as is assumed in Crehore's theory of atomic structure [see Abs. 1779 (1913)]. On the other hand, the conclusions arrived at agree well with Bohr's theory of the atom [see Abs. 15, 811, 1070 (1914)]. A. B. W.

## RADIO-ACTIVITY.

309. *Scattering of α-Particles by Gases.* **R. R. Sahni.** (Phil. Mag. 33. pp. 290–295, March, 1917.)—The method adopted in this investigation consists in allowing α-particles from the tip of a very fine needle activated with RaC to pass through a small hole (70 μ in diam.) made in a Pt diaphragm and then to strike a photographic plate placed in a suitable chamber at a known distance [see also Abs. 1060 (1915)]. The chamber contained the gas with which the experiments were to be conducted at a known pressure. After suitable exposure the plate was developed and examined under a microscope. By a method described the distribution of the silver grains in equal concentric areas was determined.

A naked-eye examination of the plates prepared with a gas at different pressures showed that while with a pressure of a few millimetres the impression was a small and dense spot, with increasing pressures it became larger and at the same time less and less dense. The impression at very low pressures was almost uniformly dark except at the extreme edges, but with higher pressures there was a gradual falling off in the density of the impression from the centre outwards. The observed effects varied with the different gases employed.

The results are considered not sufficiently accurate to deduce the most probable angle of scattering with any degree of accuracy. A. B. W.

310. *Atomic Weight of "Thorium" Lead.* **F. Soddy.** (Nature, 98. p. 469, Feb. 15, 1917.)—A note on the result of an atomic-weight determination of a specimen (12 gm.) of distilled lead separated by the author from thorite (Ceylon). This determination has been made by Hönigschmid (Vienna), who obtains, as a mean of eight determinations, the value 207·77 ± 0·014, which is in excellent agreement with that obtained by the author, 207·74, from the same specimen. This confirmation clears up many controversial matters, and we now know of varieties of lead differing from 206·08 to 207·77 in atomic weight, and from 11·273 to 11·376 in density, the atomic volume in all the cases examined being constant. A. B. W.

## HEAT.

**311.** *Limits of Inflammability of Gaseous Mixtures.* **W. M. Thornton.** (Phil. Mag. 33. pp. 190–196, Feb., 1917.)—It has been shown [Abs. 700 (1916)] that, in the upper-limit mixtures of the paraffins, the volume of inflammable gas is twice that in the mixture for perfect combustion. In the case of certain endothermic compounds, *e.g.* acetylene, cyanogen, and carbon disulphide, there is, however, three times this volume, in the case of hydrogen four, and in that of carbon monoxide six times. When the upper limits of inflammability are known for the lower terms of a homologous series, those for any gas in the series can be calculated from the equation typical of the compound. As regards the lower-limit mixtures, the paraffins form one group which, as with the upper limit, contains benzene, while acetylene, cyanogen, carbon disulphide, and the alcohols constitute another; cyanogen falls into line with the others if its combustion in the explosive wave, even in dilute mixtures, is to carbon monoxide and not to the dioxide.

It is shown that the ratio of the upper to the lower limits of inflammability should be nearly constant; with the paraffins this ratio increases slightly, and with the ethylene hydrocarbons diminishes, as the series is ascended. Since the product of the percentage L of combustible gas in the lower-limit mixture and of the oxygen atoms present per molecule of combustible gas is constant, the number of oxygen atoms is the same in unit volume of the lower-limit mixtures of all inflammable gases. These oxygen atoms are not all burnt, but as they are all raised to the temperature of ignition, it follows that they are all activated, and that the intensity of pioneering ionisation or activation of oxygen in the advancing wave-front is the same in all gases at the point where self-ignition begins.

The percentage of combustible gas in the upper-limit mixture being U and the number of oxygen atoms required for the normal combustion of one molecule of the gas, $n$, it is shown that the product U$n$ is proportional to the total heat of combustion of unit volume, and this is the same in the upper-limit mixtures of all groups of gases in which U$n$ has the same value. Both the upper and lower limits of inflammability may then be considered as controlled by the heat liberated in the reaction.

By means of the above considerations it is possible to predict the limits of inflammability of certain groups of compounds with considerable accuracy. The heavier paraffins as far as octane form the chief constituents of petrol, and refined lamp oils are composed of still heavier paraffins with a few olefines. The values of U and L have been calculated for the paraffins up to $C_{15}H_{32}$ by means of the formulæ derived from the lighter paraffins, the values of the ratio U : L being in good agreement with the experimental values. T. H. P.

**312.** *Relation of Oxygen to the Heat of Combustion of Organic Compounds.* **W. M. Thornton.** (Phil. Mag. 33. pp. 196–208, Feb., 1917.)—The heat of combustion of hydrocarbons, $C_aH_b$, may be expressed by the formula $aA + bB - \Sigma v$, where A and B are the heats of combustion of carbon and hydrogen to $CO_2$ and $H_2O$ respectively and $\Sigma v$ is the internal energy represented by the bonds. For the paraffins and related compounds $A = 105{\cdot}92$ large Cals. per gm.-mol. and $B = 52{\cdot}42$, and for aromatic hydrocarbons $A' = 107{\cdot}16$

and $B' = 51{\cdot}78$. In either case the heat of combustion of carbon is very nearly twice that of hydrogen, and this relation, which may be only accidental, leads to a singularly convenient law for the estimation of the calorific value of any hydrocarbon of known composition. Thus, the difference between the heats of combustion of successive members of the paraffins, olefines, acetylenes, aromatic hydrocarbons, alcohols, aldehydes, ketones, and esters is also nearly constant and equal to 158·59 Cals. for the radical $CH_2$. Since these effects are additive, when combustion is complete with one oxygen atom the heat set free, irrespective of bonds, is 52·4 Cals. per gm.-mol. of combustible gas; when with two atoms, 105·9; and when with three atoms, 158·59 Cals.

With hydrocarbons and other compounds it is found as a first approximation that the heat of combustion is proportional to the number of oxygen atoms which combine with a molecule of combustible gas, irrespective of molecular complexity and of whether it is carbon or hydrogen that is burnt, and is equal to $53n$ Cals. per gm.-mol. of the compound. This suggests that, as the essential feature of combustion, oxygen is first sensitised by contact with the source of ignition and becomes an extremely active agent, atoms of which are able to seize upon and tear apart the almost unresisting hydrocarbon molecule.

The complete combustion of nitromethane requires only 1·5 atoms of oxygen if the oxygen in the molecule is used in its combustion. The heat of combustion is 189·9, and $180{\cdot}9/1{\cdot}5 = 120{\cdot}5$—a value greater than with any other compound. If 1·5 is replaced by 3·5—the total oxygen required for the combustion—the value of the ratio becomes $180{\cdot}9/3{\cdot}5 = 51{\cdot}7$, which agrees with the value given above. The only meaning of such a result is that the oxygen contained in this compound takes no part in its combustion, owing perhaps to the difficulty of activating it when associated with nitrogen, and that in these cases combustion is carried out wholly by free oxygen. The part played by combined oxygen in explosives is, therefore, called in question.

From the relation $H = 53n$ the quantity of air required for the complete combustion of any hydrocarbon of unknown composition, such as petrol substitute, may be found when the heat of combustion and the vapour density $d$ are known. If the heat of combustion is given in British Thermal Units per pound, then, since the molecular weight is $28{\cdot}87d$ and there are 252 small cals. to one B.Th.U. and 454 gm. to the pound,

$$\begin{aligned} n &= \text{B.Th.U. per lb.} \times 252 \times 28{\cdot}87 \times d/(53 \times 454 \times 10^3). \\ &= 3{\cdot}025 \times \text{B.Th.U.} \times d \times 10^{-4}. \end{aligned}$$

The values of $n$ calculated for the paraffins by means of this formula, using observed calorific values and vapour densities, are very close to the known numbers and those now similarly calculated for the petrol mixtures examined by Thomas and Watson (see Clerk and Burls, "The Gas, Petrol, and Oil Engine," vol. ii. p. 452) are probably accurate to the same degree. It is noticeable that the ratio of the weight of air for complete combustion to that of vapour burnt is highest in methane (17·5), and falls rapidly to a normal value in butane (15·6); the mean ratio for all the substances is 15·5, and the variations are small. The mean number of oxygen atoms for complete combustion of the mixtures is $n = 20{\cdot}7$, corresponding with a mixture in almost equal proportions of hexane and heptane if these alone are present.

In the same way, when the calorific value of any liquid or gaseous fuel is unknown, it can be determined by finding by explosion the volume of air required to burn completely a measured volume of the vapour of unknown density. If, for example, 50 vols. of air are required for one of the vapour and the measured vapour density is 8·2, the percentage of the gas is 1·96, $n = 20{\cdot}4$, and the heat of combustion $= 20{\cdot}4 \times 10^4/8{\cdot}025d = 21{,}100$ B.Th.U. per lb. of fuel, or $H = 11{,}000$ large Cals. per gm.-mol. T. H. P.

313. *Thermodynamics and Gravitation.* **G. W. Todd.** (Nature, 99. pp. 5–6, March 1, 1917.)—The recent experiments of P. E. Shaw seem to show that the "gravitation constant" has a temperature coefficient. It is remarkable too that G seems to be only appreciably influenced by increasing the temperature of the larger attracting mass. The application of the principles of thermodynamics, while affording no explanation of gravitation itself, may offer an explanation of the temperature coefficient if it exists. One assumption only is made, namely, that the approach of an attracted mass towards an attracting centre is accompanied by a rise in temperature, or, for the approach to be isothermal, heat must be taken away from the approaching mass.

On this assumption is deduced the following law of gravitational attraction: $F = G\,(Mm/r^2) + Am \log \theta$, where A is a constant and $\theta$ is the absolute temperature of the mass $m$. This formula makes the temperature correction to gravitational attraction proportional to the mass whose temperature is raised.

Calculating A from P. E. Shaw's results gives an approximate value of $1{\cdot}4 \times 10^{-12}$. Poynting and Phillips used 208 gm. attracted by the earth and the temperature was varied between —186° C. and +100° C., whence it is found that the change would be only 1 in $5 \times 10^{14}$ which would escape detection. [See Abs. 860 (1916).]

**J. L[armor].** (Ibid. pp. 44–45, March 15, 1917.)—The Carnot cycle in G. W. Todd's letter leads by a ready extension to the result that if the force of gravitation on a body depended on its temperature, and thermodynamics were applicable, there must be interaction between the gravitational field sustained by a body and its thermal molecular energy; so that part of the exhaustion of energy of position when the field does work on the body would go to increase its store of heat, only the remainder appearing as work done. Thus when, owing to displacement of a body of mass $m$ in the field of force, work $\delta W$ is done *against* the field, so that energy $\delta W$ is gained, then also heat must be gained by the body of amount $-T/m\,.\,d/dT\,.\,\delta W$ if its temperature is not to change. There would be dissipation of energy involved in the diffusion of such heat, just as in the case of heat of compression in sound-waves of very slow period. Only in two ideal limiting cases will there be conservation, and then $\delta W$ will be the increment, arising from the displacement alone, of a function of position and also of temperature, which thus constitutes a gravitational potential W; in these cases the heat of the body will depend definitely on its temperature T and its position in the field of force, the latter contributing an amount proportional to $T/m\,.\,dW/dT$.

The two cases, of some curious theoretical interest, are (i) that of a universe isolated in an enclosure maintained isothermal by internal radiation; (ii) that of an adiabatic universe in which there is no exchange of heat by radiation or contact.

Reverting to the formula deduced, three objections are raised, as follows: If the gravitation exerted on $m$ increased by the fraction $1/k$ of itself for a rise of 1 deg. C., then at 0° C. a change of gravitational energy into work would be accompanied, on Carnot's principle, by a gain of thermal energy equal to $273/k$ of its amount, which could scarcely escape notice, unless $k$ were large.

The sign in G. W. Todd's first relation seems to require change.

His hypothesis is challenged in that it leads to a temperature term which has the same value at all distances between the masses.

**E. H. Barton.** This note asks if G. W. Todd's expression does not need some modification. Thus if the large mass M were at temperature $\Theta$, and the small mass $m$ at $\theta$, the formula would then become

$$F = G.Mm/r^2 + A(M \log \Theta + m \log \theta).$$

But even when thus generalised, it still seems unsatisfactory, since it leads to the following curious results: (1) The temperature corrections vanish at *unit* temperature. (2) At the temperature of absolute zero the attractive force becomes *minus infinity*, i.e. *an infinite repulsion!* (3) The temperature correction is given as independent of the distance $r$. Hence, for large enough distances apart, the temperature correction to the force might exceed the Newtonian value of the force itself. E. H. B.

314. *Thermodynamics of the "Throttling Process."* **L. Schames, R. Plank.** (Phys. Zeits. 18. pp. 30–32 and 33, Jan. 15, 1917.)—Plank replies to a criticism by Schames of a former paper under the above title [Abs. 146 (1917)]. It was shown in this criticism that the numerical results deduced from the author's "inversion curves" deviate greatly from experimental values. In reply to this, it is pointed out that the theory connected with air and liquid-air machines referred only to a range of temperature from that of the room to −190° C., and only in this range are thermal values dependable. To attempt to extend the application of the theory to high temperatures is not justifiable. The object of the paper was only to add something to the theory of liquid-air machines. T. B.

315. *Radiation.* **R. H. Kent.** (Phil. Mag. 33. pp. 223–224, Feb., 1917.)—Attention is here called to what is considered a fundamental fallacy in the deduction of Kirchhoff's law for radiation. To deduce it, it is necessary to establish the proposition that there is no net transfer of energy by radiation across the boundary of two abutting media when they are at the same temperature, or that the radiant energy transmitted across the boundary in unit time in one direction is equal to the amount transmitted in the opposite direction.

The reasoning by which this proposition is established is as follows: From the equality of temperature of the two media it is correctly inferred that there is no total net transfer of energy across the boundary. It is next assumed that transfers of energy due to temperature-differences are accomplished in two ways, by radiation and by conduction, and, moreover, it is tacitly assumed that the process of conduction involves no energy transfer by radiation. Then, since there is no temperature gradient, it is correctly inferred that there is no net transfer by conduction, and hence (in view of the fact that the total net transfer is zero) that there is no net transfer by radiation, which is the proposition to be established.

The fallacy referred to consists in the tacit assumption that the process of conduction involves no energy-transfer by radiation. Now conduction in the sense used in the deduction of Kirchhoff's law is a net energy-transfer, the rate of which is proportional to the vector temperature gradient. Such an energy transfer may conceivably, and in all probability does, involve a transfer of energy by radiation from molecule to molecule of the conducting substance, which in certain cases may fail to vanish with the temperature gradient. In general, for example in the interior of a homogeneous isotropic body, it is likely that the radiation part of the energy transfer involved in conduction vanishes with the temperature gradient, but across the boundary between two different media it is easily conceivable that this is not the case. Accordingly conduction and radiation do not refer to mutually exclusive classes of phenomena, and hence from the absence of energy transfer by conduction and from the fact that the total net energy-transfer is zero, the absence of net energy-transfer by radiation cannot be deduced. E. H. B.

**316.** *Energy Equipartition and Radiation.* **W. F. G. Swann.** (Phil. Mag. 33. pp. 64–82, Jan., 1917.)—Two problems are here discussed, viz. Is the equipartition theorem a necessary consequence of the application of so-called "ordinary dynamics" to a system? and, Does the application of the theorem to the problem of radiation necessitate the conclusion that Rayleigh's radiation formula ought to be true? After some general remarks on the proof of the equipartition theorem, in which attention is drawn to the distinction to be made between the purely mathematical portion of the theory and the portion involving other considerations, the question is raised whether infinite probability in the practical sense is a necessary consequence of the uniform density of point distribution in the generalised space considered in the demonstration. The Hamiltonian equations do not necessitate constancy in the relative configurations of the points, but only in their density. The points might, *e.g.* be thinned out along the path of a stream line provided that they were crowded to a corresponding extent perpendicularly to it. Thus, suppose all the copper in the universe divided into equal blocks, and choose for examination all having temperatures such that E lies between E and E + *d*E. Then the differing states of these blocks may be treated as if successive states of one block or system. A finer mathematical analysis than one taking account only of the centres of gravity of the molecules, or of the atoms, such, *e.g.* as that provided by the electron theory, would take account, not only of the possible system of coordinates corresponding to copper, but of all mathematically possible distributions of the electrons. It then becomes conceivable that the practical permanence of the copper, as copper, should not be represented by the coordinates all lingering near certain definite values: the abnormal regions of the generalised space might then be distributed over great distances in the space like a thin channel permeating, hither and thither, a solid block in three-dimensional space. The continuity of flow of the representative points from the normal to the abnormal regions might then be preserved without the times during which the points remain within the abnormal regions being constrained to be very short, and without any congestion of the points such as would infringe the Hamiltonian conditions as expressed in Liouville's theorem of differential invariance.

Several examples are discussed of apparent conflicts between experimental results and the equipartition theory arising from unjustifiable application of the latter. One of these is the statement often made that the theorem involves the equipartition of energy between the electrons inside the atoms and the free electrons outside. It is not sufficient to compare the average energies of the two groups at the instant of grouping. Each must be followed over a very long period, and during this period entries of electrons into atoms and exits from them will obliterate all distinguishing characteristics between the two groups, with regard to which the theorem states merely that their average energies will be equal except in a relatively infinitesimal portion of isolated cases. Such cases are obviously artificially brought into prominence when the groups are initially arranged so that one contains only electrons which are inside atoms, and the other contains only electrons which are outside atoms. It is frequently argued that the equipartition theorem leads to the conclusion that the energy of a system specified by an infinite number of coordinates must be infinite, the argument being somewhat as follows:—If a perfect gas of temperature T form part of the system, and if RT/2 be the average energy of a degree of freedom of the gas, then equipartition requires that the average energy of any other degree of freedom shall be RT/2. Since, in the case of radiation, the number of modes of motion in the ether—and so the number of coordinates—is infinite, and since R is measurable and finite, the total energy must be infinite. Apart from the question as to whether the theorem can be properly applied in the case of an infinite number of degrees of freedom, the question arises whether the R in the energy expression can be identified with the gas constant R. This would be so if the energy were expressible as the sum of squared terms, part of the sum involving the ethereal modes of motion, and part involving the velocity coordinates of the molecular centres of gravity; but this would involve the obviously incorrect assumption that the interaction between the radiation and the gas was completely expressible in terms of interaction between the waves and the molecular centres of gravity. The matter stands somewhat in the following light:—The whole energy of the system is approximately expressible as the sum of squared terms corresponding to the molecules alone, and we may reasonably expect approximate equipartition between these terms, together with an approximate conformity to the so-called perfect gas laws. Such a specification can, however, tell us nothing about the radiation or its relation to the gas constant; for it is only by the neglect of the radiation that the approximate equipartition results. The energy may, however, be expressible approximately, or possibly exactly, in a much more fine-grained manner, as the sum of squared terms, some of which correspond to the modes of ethereal vibrations, and some of which owe their origin in some way to the matter, and are apart from what is ordinarily understood as radiation. When this mode of expression is adopted, it becomes necessary to introduce into the statistical theory determining the partition of energy between the different terms, those restricting relations, whatever they are, which provide for the permanent existence of the molecule as such. It may be that some law other than equipartition will result; but even if equipartition does result, it is not to be anticipated that the average energy of one of the coordinates which correspond to the system as expressed in this fine-grained manner will have any connection with the average energy of a coordinate of the system when the latter is expressed in the entirely different and approximate manner in terms of the ordinary coordinates and momenta of the molecules.

In spite of such objections to connecting the gas constant R with Rayleigh's radiation formula through the medium of arguments of the kind here criticised, there remains the remarkable fact that the R which occurs in the formula, which is found to be true for long waves, is identical with the gas constant determined experimentally, and the author appends some interesting suggestions tending to the conclusion that this constant should be regarded as originating in the radiation formula for long waves, and appears experimentally as gas-constant only because we take as the measure of temperature a quantity proportional to the average energy of a degree of freedom of a gas molecule. G. W. DE T.

# ELECTRICITY AND MAGNETISM.

## THEORY, ELECTROSTATICS, AND ATMOSPHERIC ELECTRICITY.

317. *Unipolar Induction: Existence of the Ether.* **E. H. Kennard.** (Phil. Mag. 33. pp. 179–190, Feb., 1917.)—An experiment is described showing that a cylindrical condenser rotating inside a magnetised coaxial solenoid becomes charged as required by the theory of Lorentz. Rotation of the solenoid has no effect (Barnett).

The disproof of the moving-line theory is thus completed; electromagnetic induction depends in part upon absolute rotation in the mechanical sense. Analysis in terms of electrons seems to make necessary the existence of a stationary ether in order to explain the observed effect; so that the phenomenon seems to present difficulties for those relativitists who reject the ether. [See Abs. 1859 (1912) and 210 (1913).] E. H. B.

318. *Electromagnetic Wave Propagation in Wires.* **H. Saegusa.** (Tôhoku Math. J. 5. pp. 317–324, Dec., 1916.)—Erroneous expressions for Heine's function $K_0(x)$ and its derivative were used by A. Sommerfeld [see Abs. 570 (1899)] in the development of the theory, and were reproduced in G. Mie's further investigations [Abs. 2027 (1900)], as was done by A. Gray and G. Matthew in their Treatise on Bessel's Functions, published in 1895. The present paper gives the modifications in the formulæ of these two papers which result from introducing the correction here indicated. G. W. DE T.

319. *Energy in the Electromagnetic Field.* **E. A. Biedermann.** (Phil. Mag. 33. pp. 146–157, Jan., 1917.)—It is an immediate deduction from experimental results that the mutual energy of two circuits is represented by the expression

$$T_m = i_1 i_2 \iint \frac{\cos\epsilon}{r} ds_1 ds_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where $\epsilon$ is the angle between $ds_1$ and $ds_2$. If, however, the value of $T_m$ be derived from a general expression by the mutual energy of a system of moving charges, a different result is obtained, viz.—

$$T_m = \tfrac{1}{2} i_1 i_2 \iint \frac{\cos\epsilon}{r} ds_1 ds_2 + \tfrac{1}{2} i_1 i_2 \iint \frac{\cos\alpha_1 \cos\alpha_2}{r} ds_1 ds_2 + \ldots\ldots (2),$$

where $\alpha_1$ and $\alpha_2$ are the angles made by $ds_1$ and $ds_2$ with the line joining them. These expressions are not, in general, equivalent. Now (1) is the result of integrating over all space the square of the mean value of the magnetic force at a point; while (2) is the result of integrating the square of the instantaneous magnetic force and then taking the mean with regard to time. It follows that $\mathbf{H}^2/8\pi$ does not represent the kinetic energy density in the field, if by **H** is understood the *instantaneous* value of the magnetic force at a point, but only if **H** were taken to represent the mean value of the magnetic force at the point. And these are not identical, since the motion constituting a current is not distributed uniformly throughout a conductor, but concentrated in a number of discrete particles, though in any ordinary circuit the number of moving electric particles is so great that, at all points *exterior* to the conductor the variation in the magnetic force is negligible. Writing $\mathbf{G} = \Sigma \mathrm{RV} \cos\theta/\mathrm{C}$, where R is the electric intensity in E.S.U. at a point due to any single charge, and $\theta$ the angle between the directions of R and the velocity V of the charge, the author shows that the mutual value for two circuits of $\int(\mathbf{H}^2 + \mathbf{G}^2)dv/8\pi$ is

$$\sum\sum\frac{e_1e_2}{r}(u_1u_2 + v_1v_2 + w_1w_2) = i_1i_2\int\int\frac{\cos\epsilon}{r}ds_1ds_2$$

when $u_1$, $v_1$, $w_1$, and $u_2$, $v_2$, $w_2$, are the velocity components of the charges in the two circuits respectively. Therefore, if the instantaneous kinetic energy density at any point of the electromagnetic field be represented by $(\mathrm{H}^2 + \mathrm{G}^2)/8\pi$, instead of by $\mathbf{H}^2/8\pi$, a correct value will be obtained for the mutual energy of the two circuits, and the author suggests, therefore, that this may be a correct representation of the instantaneous kinetic energy density in all cases. The argument is identical with that used in concluding from the theory of point charges in magnetism that the energy density is $\mathbf{H}^2/8\pi$. **H** is then constant at a given point (for a static system of magnets) within or without magnetic matter, because the latter is regarded as infinitely divisible into elements of magnetic moment, which corresponds to assuming the moving electricity in a circuit to be distributed continuously throughout a conductor. The author's expression for the energy density leads to some interesting results. When applied to a system of charges moving with a common velocity, the mass is as if the Faraday tubes had a mass $\mathrm{R}^2/4\pi c^2$ per unit volume, where R is the *resultant* electric intensity, whereas on the ordinary $\mathbf{H}^2/8\pi$ assumption the mass of the tubes varies from the above value for motion at right angles to the tubes to zero for motion in their direction. Assuming a finite velocity of propagation, Maxwell's equations are shown to be derivable by applying Lagrange's equations to a Lagrangian function obtained by assuming the kinetic energy in the field to be that suggested by the author, and the potential energy to be equal to the electrostatic energy of the system. The generalised form then obtained for **G** leads to the expression of the kinetic energy density in the most general form by

$$\frac{1}{8\pi}\left(\mathbf{H}^2 + \mathbf{G}^2\right) = \frac{1}{8\pi}\left\{(\mathrm{curl}\ \mathbf{A})^2 + (\mathrm{div}\ \mathbf{A})^2\right\},$$

where **A** is the vector potential.

**G. H. Livens.** (Ibid. pp. 286–290, March, 1917.) G. W. DE T.

**320.** *Reciprocity of Electric and Magnetic Actions.* **J. B. Pomey.** (Rev. Gén. d'Él. 1. p. 9, Jan. 6, 1917.)—Laplace's formula gives the intensity at a point P of the vector magnetic field **H**, due to an element of current $i\delta s$ situated at MM′. Replacing the element $i\delta s$ by a charge $e$ at M moving towards M′ with velocity **U**, and denoting the distance MP by $r$, Laplace's formula then becomes, in vector notation, $\mathbf{H} = [e\mathbf{U}, \mathrm{grad}\ (1/r)]$. This gives the magnetic field created by the displacement of the electric charge $e$. The present paper is devoted to finding an expression for the electric field **E** created by the displacement of the magnetic mass $\mu$, having the same velocity **U** as the charge $e$. The formula finally obtained is $\mathbf{E} = [\mu\mathbf{U}dt, \mathrm{grad}\ (1/r)]$, where $dt$ is the time element required for $\mu$ to move through the elementary distance MM′. A. W.

**321.** *Analogies between Mechanical and Electrical Phenomena.* **J. B. Pomey.** (Gen Rév. d'Él. 1. pp. 163–165, Feb. 3, 1917.)—The theory of mechanical impulses is applied to electrical phenomena and in particular to oscillating circuits. The equations of Lagrange applied to these circuits show that the oscillations are always accompanied by magnetic loss of energy that is dissipated by the production of a spark. A. J. M.

**322.** *The Electromagnetic System of Units.* **E. Brylinski.** (Rev. Gén. d'Él. 1. pp. 43–46, Jan. 13, 1917.)—The five fundamental equations which determine the dimensions of the electrostatic and electromagnetic units are first written down, and the grave inconvenience of having two systems of units is pointed out. The question has been unnecessarily complicated by the adoption of a third system which is known as the practical system of units. The adoption of a secondary unit of current equal to one-tenth the absolute unit of current is quite indefensible, as it introduces a great variety of numerical multipliers which are difficult to remember. The author discusses each unit separately, and shows how inconvenient some of them are. In order to obtain a homogeneous system of units which will apply to mechanical, electrical, and magnetic quantities, he suggests that the following four units be taken as fundamental—the unit of length, the unit of time, the unit of electric current, and the unit of electric resistance. The centimetre would be the unit of length, the second the unit of time; the ampere defined at the London Conference, the unit of current; and the ohm defined at the same Conference, the unit of resistance. It may be objected that the electric units may be difficult to realise in practice, but the author points out that they are no more difficult to fix than the second. The electrical units would thus be maintained, but the new unit of force would be 10 megadynes, *i.e.* 9·81 kg. weight, and the unit of mass would be 10 million gm., that is, 10 French tons. The unit of force is quite suitable, but the unit of mass is great, although possibly it is less inconvenient in mechanical engineering than the gramme. With the new system of units the error made in calling both the unit of magnetic field and the unit of magnetic induction by the same name, the gauss, would have been impossible. A. R.

## DISCHARGE AND OSCILLATIONS.

**323.** *Effect of a Magnetic Field on the Initial Recombination of the Ions produced by Röntgen Rays in Air.* **G. E. M. Jauncey.** (Am. J. Sci. 42. pp. 146–150, Aug., 1916.)—The work was undertaken with the object of testing the direct effect of a magnetic field on the ionisation current in air at atmospheric pressure when the applied voltage is either above or below the saturation voltage. In experiments with voltage above saturation homogeneous secondary X-rays from Cu were used. Detailed experimental data with diagram of connections are given. In these experiments the effect of a magnetic field on the total ionisation produced by X-rays is examined. The given table of results shows that the magnetic field of the intensity here used, and consequently the bending of the secondary kathode rays into curvilinear paths, does not alter the total ionisation produced in a gas by X-rays. With voltage below saturation the results obtained lead to the conclusion that a magnetic field has no effect on the saturation curve, and therefore no effect on the initial recombination of the ions. A. E. G.

**324.** *Light produced by the Recombination of Ions.* **C. D. Child.** (Phys. Rev. 9. pp. 1–14, Jan., 1917.)—Certain phenomena connected with the luminosity of the vapour rising from the mercury arc indicate that this light is produced by the recombination of ions, and that the vibrations of the atoms producing light are not started when the atoms are broken into ions, but when the ions recombine to atoms [see Abs. 827 (1916)]. Since this conclusion is contrary to that held by some who have investigated the problem of the production of light from a different standpoint, it is desirable to modify in some way the experiment to which reference has been made. In that experiment the current was continuous, and the vapour was examined after it had moved away from the region where the current was flowing. The experiment can be modified by stopping the current and examining the vapour in the place where the current has been flowing—that is, by examining the light from an alternating-current arc at the moment when no current is flowing. If the light is due to recombination it will in either case continue for a time after the current has ceased flowing through the vapour. If the light is due to ionisation it will cease when there is no ionisation, and this occurs when no current passes through the vapour. An examination of the light at different phases has already been made by Fleming and Petavel, and they found that at the moment when there is no current there is a very appreciable amount of light given off, not only by the carbons, but also by the gas between the carbons; they also found that the minimum of light occurs after the time when the current is zero. It occurs, in fact, at approximately the same time as the minimum of conductivity, that is, the time when there is the least number of ions. These experiments were made before the electron theory of discharge was developed, and no attempt was made to explain the results. It is evident, however, that the phenomena observed are what must occur if the light is due to recombination. It is also possible to suggest other explanations when carbon electrodes are used in air. For example, the light which appears when there is no current may be due to the oxidation of the hot gases between the electrodes. It therefore seemed desirable to repeat the experiments of Fleming and Petavel, using mercury terminals in a vacuum instead of carbon electrodes in air. The apparatus used was essentially the same as that employed by Fleming and Petavel. Their work on the intensity of the light from an a.c. carbon arc at different phases was repeated, and a similar study was made of the flaming arc and mercury arc in a vacuum.

It is found that in every case the intensity of the light passes through a minimum without entirely vanishing, and this minimum occurs after the current passes through the zero value. The results obtained with the mercury arc are entirely in harmony with the view that part, at least, of the light coming from that arc is due to recombination of the ions, since there is no chance for oxidation or other known chemical action. The time of max. intensity occurs after the time of max. current, and the light continues after the current ceases, as is required by such a view. Moreover, if the light is due to recombination, the intensity of light must be greater, the greater the number of ions present. The number of ions present is very approximately proportional to the conductivity of the gas, and this in turn is proportional to the current divided by the p.d.; and it is found that this relation exists. Through a large part of the period the voltage is nearly constant, and the luminosity changes as the current. At the end of the period both the current and the voltage decrease, but the light is roughly proportional to the ratio between them. On the other hand, these facts are not in harmony with the view that the light is caused by a vibration produced when the atoms are ionised, unless it is

assumed that the atoms continue to vibrate for a comparatively long time after the impact is made which starts the vibration. In the work here described the light continues for at least 1/30 of a cycle after the current ceases, that is for 1/1800 sec. The difficulty of explaining this continuance of the light has already been shown by the author. Strutt also mentions this difficulty, but expresses the belief that it can be eventually explained.
A. E. G.

**325.** *Positive Ionisation from Hot Salts, and some Observations on the Properties of Molybdenite at High Temperatures.* **A. T. Waterman.** (Phil. Mag. 33. pp. 225–247, March, 1917.)—From experiments with various salts the following general conclusions have been reached, although there are exceptions. Positive emission:—Characteristic of the metallic constituent. Negative emission:—Electrons accompanied in some cases by an emission characteristic of the remaining constituent. The metals whose salts (chiefly the halides and sulphates) have been investigated are:—Alkaline group: K, Na, Li, Pb, Cs. Alkaline-earth group: Be, Mg, Cd, Zn, Sr, Ca, Ba, Al, Mn, Fe. Of these the Zn and Cd halides give a positive emission consisting of doubly charged atoms. Mn and Al vary considerably in their emission, so that nothing very definite can be said about them. Be and Fe apparently give only the K-impurity emission like that from the pure metals. All the rest yield a positive emission consisting of singly charged atoms of the metal. The question naturally arises as to the reason for obtaining a singly charged ion in some cases and a doubly charged in others; this does not appear to be connected simply with the valence as might be expected. In other words, is it possible to predict what the emission from a given salt will be?

These experiments were instituted with a view to attempting an answer to this question. Only positive emission was considered and a number of salts were tried, the metals of which differed in valence. The method is briefly as follows: The salt is placed on a narrow strip of Pt whose emission has previously been driven out by continued heating to a temperature above which measurements with the salt are to be made. The salt is then heated by passing a current through the strip, and the temperature roughly ascertained from the resistance of the strip. If now the strip is raised to a certain potential, emission from the hot salt is driven off. A magnetic field is then applied which deflects the stream of ions. The amount of this deflection is taken when the magnetic field is reversed. The accuracy of the results is found to depend upon the accuracy with which the distance between the strip and the plate receiving the ions can be measured and kept constant. Two methods of mounting the strip to accomplish this end are described. The values obtained for $m/H$ for AgCl and AgI do not point to any characteristic silver emission which can be detected; the numbers were quite consistent and averaged a little lower than the K-impurity emission from metals, for which $m/H = 39$. From the values of $m/H$ for $Cu_2Cl_2$ it certainly would seem as if a Cu++ ion had been detected. In any case there is probably no emission of Cu-ions under 1000° or so. At this temperature and pressure, however, the salt must long since have been vaporised. If there is an emission of Cu-ions, then it seems likely that it must come from the action of Pt on the vapour. This was shown to be possible by Sheard. With $CuCl_2$, $2H_2O$ there does not seem to be anything more than the regular impurity emission. The value $m/H = 36{\cdot}3$ is, however, a little low. As $CuCl_2$ is supposed to go over into $Cu_2Cl_2$ at 500° this may be taken as evidence that the emission from $Cu_2Cl_2$ is not characteristic Cu emission, but a combination of K and Na impurities for instance. Nevertheless, it is difficult to ascribe the very distinct values about 32 to an increase in the distance between strip and plate. The values of *m*/H for $PbCl_2$ and $PbBr_2$ are fairly consistent. There is no evidence of an emission characteristic of the Pb. The values seem quite evidently to be due to K as an impurity. It is possible that a characteristic emission of Pb was obtained with $PbBr_2$ as a very slight emission was detected from 100° to 400°; it was, however, too slight for measurement. The values of *m*/H for $AlF_3$ at first ranged about 55, coming steadily down as the temperature increased to 43. The values for $Al^+$, $Al^{++}$, and $Al^{+++}$ would be $m/H = 27·1$, 13·5, and 9, respectively, so that there is apparently no Al emission at the above temperatures. No emission was found with platinum chloride characteristic of Pt, unless it be taken as significant that $PtCl_4$ and a Pt strip give practically the same value of *m*/H. The presence of glass as an impurity would warrant a lowering of *m*/H due to Na compounds contained. The emission seems to be without doubt due to K as an impurity.

Sources of impurities are next considered in detail. The investigation has therefore not shed much light on the question of the connection between valency and the charges on the ions. In nearly every case positive ions have been found to be present for which the value of *e*/*m* corresponds to singly charged atoms, either of K or Na, or of both these elements, so that the results confirm the conclusion previously reached by Richardson. It is possible that the characteristic emission from these salts occurs but is too small for measurement with the apparatus used. Molybdenite is found to possess the following electrical properties: (1) In the range of temperature between that of the room and a brilliant red heat this mineral exists in two distinct states. (2) The resistance in the low-voltage or low-temperature state is very nearly an inverse exponential function of the absolute temperature. (3) At ordinary room temperatures the resistance is a function of the applied p.d. and appears to approach the value infinity as the potential approaches the value zero. (4) The conduction of electricity is evidently carried on mainly by electrons. Two conclusions may be stated in regard to the thermionic emission from molybdenite. I. A large emission from impurities, principally the ordinary $K^+$ emission. II. A characteristic emission of $Mo^+$ ions apparently having no exclusive relation to the break or to either state.

A. E. G.

**326.** *Ionisation Potential of Helium.* **C. B. Bazzoni.** (Phil. Mag. 32. pp. 566–575, Dec., 1916.)—The energy of impact necessary to remove an electron from simple atoms can be calculated directly from Bohr's theory. The application of Bohr's formula to helium indicates that an energy corresponding to that of an electron falling through 29·3 volts is necessary to remove one electron from the helium atom, and that to remove both electrons a fall through 83·4 volts would be necessary. Franck and Hertz [Abs. 659 (1913)] obtained experimentally the value 20·5 volts for the ionisation potential; and Pawlow [Abs. 1710 (1914)] obtained a result, 20 volts, in good agreement with this. Recently Compton obtained a value of 22·5 volts, his calculation being based on various recorded data on helium ionisation. Experiments now described, made with an improved type of apparatus, in which both the primary electron current and the extra current to which it gives rise could be measured directly, seem to have definitely established that ionisation takes place in helium under an applied potential of about 20 volts.

This fact can be reconciled with Bohr's theory only by making certain new assumptions as to the mechanism of impact ionisation in helium. These new assumptions have not yet been subjected to experimental investigation.
A. W.

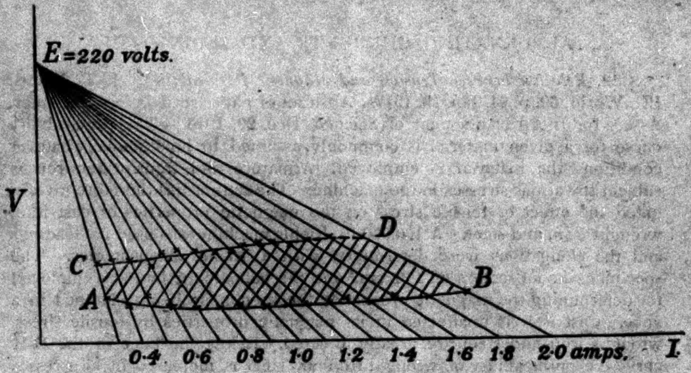
327. *Luminous Efficiency of Electric Arc.* **E. Karrer.** (Frank. Inst., J. 183. pp. 61–72, Jan., 1917.)—Describes a method for obtaining the luminous efficiency of an arc by means of two thermopiles and galvanometers. In front of one thermopile is placed a cell containing the solution necessary to give the thermopile the same sensitivity curve as that of the average eye, while the second thermopile is open to the total radiation. Experiments were made on 11 different arcs comprising both ordinary carbon and flame arcs of both white and yellow varieties, and the curves obtained from these arcs showing the relation between (1) the luminous efficiency and the current, (2) the luminous efficiency and the length of the arc, (3) the luminous efficiency and the rate of energy consumption, are given in the paper, as well as a table of the experimental results found. J. W. T. W.

328. *Discharge Images on Photographic Plates.* **K. Hansen.** (Elek. Zeits. 37. pp. 610–611, Nov. 9, 1916.)—Lay a bromide plate on a sheet of lead, bromide film uppermost; connect the sheet of lead and the bromide film with the terminals of a static machine worked for a few seconds; develop the plate. Or, instead of bringing a wire direct to the bromide film, bring it to a coin laid upon the film; on development an image of the coin appears.
A. D.

329. *Effect of Atmospheric Moisture on Electric Wave Paths.* **F. Schwers.** (Phys. Soc., Proc. 29. pp. 150–157; Disc., 158, 1917.)—Kiebitz [Abs. 1488 (1913)] has calculated the effect of atmospheric moisture on the refraction of the space-waves towards the earth on the assumption of the constancy of the expression $(K-1)/(K+2)\rho$ during the passage from liquid to gas, with the result that the refraction under average atmospheric conditions should increase the intensity at the receiving antenna only to a very small extent. The author, however, gives examples showing that this assumption is untenable, especially where K is high in the liquid state. In the absence of more accurate data for ordinary temperatures, the author calculates the values of K for water-vapour by extrapolation from Baedeker's high-temperature observations (Zeits. Phys. Chem. 42. p. 569, 1913), giving figures which are almost certainly too low. They lead to the conclusion, however, that under average atmospheric conditions with regard to temperature gradient, etc., over the ocean, the lower 1000 or 1500 metres of the atmosphere will refract the waves earthwards to a sufficient extent to cause the greater part of the space-waves to reach the receiver. G. W. DE T.

330. *Oscillating Arcs in Ether.* **A. Rönnholm.** (Ark. för Mat., Astron. och Fysik, Stockholm, 11. No. 4. pp. 1–46, 1916. In German.)—An extensive series of tests on the conditions requisite for the production of oscillations in a capacity-reactance circuit connected in parallel with an arc between metal electrodes immersed in ether. The electrodes were cylindrical and of 5 mm. diam. and various materials were employed. It was found that for each value of the external resistance R in the arc circuit there were certain maximum and minimum values of the current I in the arc between which the arc could be maintained and other max. and minimum values of the current between which oscillations were produced. If E is the line voltage (220 volts in

the experiments) and V is the voltage across the arc, the curves for V as a function of I for different values of R are a series of straight lines as shown in the Fig., in which the lines AB and CD are drawn through the max. and minimum values of the currents for which oscillations were produced. The Fig. reproduced is for copper electrodes in ether shunted by a circuit containing an inductance $L = 4{\cdot}18 \times 10^6$ cm. and a capacity $K = 1{\cdot}46 \times 10^3$ cm. The shaded area indicates the range over which oscillations are produced. This figure is typical of a great number of similar figures reproduced in the paper for arcs between electrodes of various materials shunted by circuits of various inductance and capacity. A comparison of the series of figures given in the paper shows that the region of oscillations (the shaded area) increases with increasing capacity K and decreases with increasing inductance L; that the introduction of resistance in the oscillating branch impedes the formation of oscillations; that the region of oscillations decreases with the conductivity of the material of which the electrodes are made, *e.g.* is greatest for copper electrodes, smaller for Al electrodes, and smallest for iron electrodes; that if the two electrodes are made of different materials, the anode has greater influence on the generation and maintenance of oscillations than the kathode, if the former is of such a material as to reach a considerably higher temperature than the latter; that the frequency of the oscillations increases with the current for constant length of arc and decreases with increasing length of arc, but that the influence of these factors decreases as greater currents are employed; and lastly, that the frequency is independent of the material of which the electrodes are composed. The oscillations are not pure, but contain harmonics, every order up to the 15th having been observed.



A. J. M.

## ELECTRICAL PROPERTIES AND INSTRUMENTS.

**331.** *Lubrication of Resistance-box Plugs.* **J. J. Manley.** (Phil. Mag. 33. pp. 212–215, Feb., 1917.)—The experiments give quantitative data concerning the influence of lubrication on the resistance of plug contacts. A box of coils with 9 plugs was studied and the joint resistance of the contacts determined by Carey Foster's method. The plugs were then loosened, reseated, and their resistance again determined; these several operations were performed 10 times, and from the 10 independent values a final mean value was calculated. With the plugs unlubricated a variation of ± 72 % from the mean value (0·0018 ohm) was observed. Immersing the contacts in a bath of Geryk pump oil; smearing with pump oil; or with medicinal paraffin oil reduced this variation to ± 20 %; the value being sensibly the same for all. Smearing the plugs with vaseline was even more efficient in promoting an invariable plug resistance since in this case the variation was only ± 8 %. The improvement produced by lubrication was particularly marked in the case of second-class resistance boxes. E. G.

## ALTERNATING CURRENTS AND MAGNETISM.

332. *Relation between Tension and Magnetic Permeability.* **J. T. Rood.** (El. World, 69. p. 94, Jan. 13, 1917. Abstract of paper read before the Amer. Assoc. for the Advancement of Science, Dec. 29, 1916.)—The permeability curve for a given material is commonly assumed to hold under whatever conditions the material is employed. Armature and transformer iron is subject to various stresses in the machine. The author has therefore investigated the effect of tensile stress on the magnetic properties of cast iron, wrought iron, and steel. A 100,000-lb. Riehle machine was used for loadings and the elongations were determined with a Riehle extensometer. The specimens had a section of 1·32 cm.$^2$ and the ballistic method was employed for determining the magnetic properties, the specimens being clamped in a yoke. Cast iron is unaffected in its magnetic properties by tensile stress, wrought iron and steel are greatly affected. Below the knee of the B-H curve the permeability of wrought iron and steel is increased by all stresses up to a certain maximum, the maximum varying with the material. The increase may amount to 20 %. For stresses beyond this the permeability is decreased up to the elastic limit. The decrease may be as much as 15 %. Above the knee of the B-H curve the permeability of wrought iron and steel is decreased by extensional stress and may reach 8 %. The reversal effect at low stresses can be accounted for by assuming that the effect of tension is, first, to twist the molecules so as to bring their axes parallel to the direction of the stress and then to separate them. L. L.

333. *Reversible Magnetic Permeability at High Frequencies.* **W. Kaufmann.** (Phys. Zeits. 17. pp. 552–554, Nov. 15, 1916.)—The author follows Gans in his ideas on reversible magnetic permeability [Abs. 147 and 546 (1911)]. The present paper briefly describes research on the permeability of iron for alternating fields of small value, the frequencies ranging from 680 per sec to about $10^6$ per sec. The iron used was ordinary "flower" wire, and the experiments showed the permeability to be completely independent of the frequency within the range employed. It is possible, however, that if frequencies approximating to the natural frequencies of the molecular magnets were employed, a considerable increase in the permeability would be observed. A. W.

334. *Influence of Iron Minerals on Magnetic Perturbations.* **V. Carlheim-Gyllensköld.** (Ark. för Mat., Astron. och Fysik, Stockholm, 11. No. 20. pp. 1–5, 1916.)—To illustrate the possible action of masses of iron present in the earth's crust on the perturbations of terrestrial magnetism, an analysis

is given of the theoretical effect produced by a magnetisable body limited by a surface of the second degree. Actual experiments could be made in the neighbourhood of the iron-ore deposits in Lapland, where the concentration is very definite. C. P. B.

## RADIOGRAPHY AND ELECTROPHYSIOLOGY.

**335.** *Remarks upon Pastilles.* **L. A. Levy** and **H. J. Stenning.** (Röntgen Soc., J. 13. pp. 13–17; Disc., 17–21, Jan., 1917.)—The great variation in the rate of colour change exhibited by pastilles obtained from various sources made it desirable to investigate as fully as possible the effect of the variation of different factors upon the colour change shown by pastilles prepared from barium platinocyanide. It is usually supposed that the change in colour of a barium platinocyanide pastille is due to the dehydration by the loss of two molecules of water of crystallisation to the red dihydrate. This, however, is not the case: the colour change is due to the gradual conversion of the green crystalline to the red amorphous form. This conversion may also be effected by means of mechanical pressure, as, for example, by blows from a hammer—in fact, it is possible to match any tint by varying the number of blows given. The same colour-change can also be brought about by heat, but in this case it is a true dehydration effect. It is for this reason that pastilles must not be placed too near to the bulb of the X-ray tube. One point which is well worth noticing, is that the size of the crystals has a considerable effect on the rate of colour-change, and if crystals of two different sizes, but otherwise identical, are exposed to the same radiation for a few minutes the larger crystals assume a considerably deeper tint. A given tint with the standard pastille is arrived at much more rapidly with a hard tube than with a soft tube, and the time required for the erythema dose with a certain number of milliamps. depends upon the hardness: the time is, roughly speaking, inversely proportional to the hardness. The fast pastille also changes colour more rapidly when exposed to harder radiations. The increase in speed, however, is not so great as is the case with the standard pastille. The measurement of the pastille is accurate at different distances. When using pastilles, therefore, it is only necessary to make sure that the pastille is placed at a distance from the anode equal to half the distance of the anode from the skin of the patient. It is unnecessary, as is sometimes supposed, to keep the pastille at 7·5 cm., and with some tubes this is not practicable. The number of milliamp.-minutes required to turn the pastille to a given colour increases rapidly when heavy currents are used. Pastilles after exposure can be brought back to nearly their original colour by exposing them to daylight, a northern light being preferable to direct sunlight, which latter may permanently injure the pastille if very strong. They also tend to regain their original colour when exposed to artificial light, and for this reason it is important that the colour measurement be made as quickly as possible.

A new type of chromo-radiometer for use in conjunction with dosage pastilles is described. A. E. G.

**336.** *Arrangement for the Production of Continuous High-tension Currents for use with Röntgen-ray Tubes.* **O. M. Corbino** and **G. C. Trabacchi.** (N. Cimento, 11. pp. 361–376, May–June, 1916.) The paper is divided into the following sections: Apparatus for alternating currents; Apparatus for continuous currents; Apparatus for three-phase currents. Full working details are given in each, with the necessary diagrams showing connections. A. E. G.

## CHEMICAL PHYSICS AND ELECTRO-CHEMISTRY.

337. *General Twin Series of the Atoms.* **A. van der Broek.** (Phys. Zeits. 17. pp. 579–581, Dec. 1, 1916.)—An attempt is made to refer regularities in the series of atomic weights to a general twinned series of atom types instead of the elements. T. H. P.

338. *Notes on Pearlite.* **H. M. Howe** and **A. G. Levy.** (Iron and Steel Inst., J. 94. pp. 210–232; Disc. and Corres., 233–242, 1916.)—A steel containing 0·092 % carbon, 0·14 % silicon, 0·011 % sulphur, 0·009 % phosphorus, and 0·128 % manganese has been studied with a view to determining the effects of the conditions of heating and cooling on its properties and microstructure and also on the position and length of Ar1. Samples were heated to a temperature between 800° and 900° C., called T max., and then cooled at a predetermined rate. The results show that increasing the rate of cooling causes a marked lowering of Ar1, amounting to at least 100 deg. C. In fact in the fastest coolings a lowering of as much as 200 deg. C. was observed. At the same time the time interval of Ar1 is shortened to as much as threefold by very rapid cooling. Raising T max. from 800° to 900° lowers Ar1 by about 5 deg. C. The rise of temperature during Ar1 at first increases with the rapidity of cooling, attains a maximum in a retarded air cooling, and thence decreases to zero. These effects are referred to variations in the degree of undercooling, or, in other words, to variations in the gap between Ac1 and Ar1. Two principles are involved: (I) the farther the temperature sinks below Ac1 the greater is the impulse towards transformation, increasing the number of nuclei and hence the rate of change, and (II) the higher and longer the heating above Ac1 the greater the destruction of the existing nuclei. In the progressive change in the microstructure from the hardest to the softest states the following stages may be recognised with advantage: martensite, troostite, osmondite, sorbite, sorbitic pearlite, sub-lamellar pearlite, lamellar pearlite, reefy pearlite, beaded pearlite, and granular pearlite. In troostite the transformation is incomplete, while in sorbite it is complete. Sorbite is described as being irresoluble under 500 diameters magnification. Lamellar and sub-lamellar pearlite can only be formed by appropriate cooling from one of the higher stages; they are not obtainable by reheating the granular pearlites. The formation of lamellar pearlite is favoured by an intermediate rate of cooling, and that formed by cooling from 900° is more stable than that formed by cooling from 800° C. Increase of T max. increases the coarseness of the pearlite. The microstructure is determined by the last heating and cooling past Ar1. Increasing the rate of cooling increases the strength and lowers the ductility. Specimens cooled from 800° are less strong and more ductile than those cooled from 900°. Their elastic ratio is, however, higher—a fact provisionally ascribed to a finer microstructure. It is possible that a prolonged exposure to 800° C. will have the same effects as a short exposure to 900° C. F. C. A. H. L.

339. *Some Properties of Ingots.* **A. W.** and **H. Brearley.** (Iron and Steel Inst., J. 94. pp. 137–170; Disc. and Corres., 171–192, 1916.)—The authors discuss the progress of crystallisation of steel in an ingot mould and indicate

the lines and planes of intersection of the crystal growths in different directions determined by the sides and bottom of the mould. These lines and planes are of extreme weakness, not only because of the contact of different groups of crystals, but also because of their being the collecting grounds for segregates and gas cavities. The preparation of small ingots cast with molten stearine has thrown much light on these points and also upon the relation between strength and casting temperature. It has been demonstrated that the freezing of an ingot takes place by a continuous thickening of the solid envelope in planes parallel to the walls and base of the mould. This at once indicates advantages of the taper ingot mould with the wide end upwards; freezing occurs in such a way as to leave the liquid metal open at the top, so that no secondary pipe is formed as is the case in ingots cast narrow end up. Other advantages of the ingot cast wide end up are referred to. The principles involved in the production of sound ingots are discussed at some length, and details of a mould for bottom casting and of a superimposed feeder head are given.

F. C. A. H. L.

**340.** *Relative Merits of Various Agents for the Deoxidation of Steel.* **H. M. Boylston.** (Iron and Steel Inst., Carnegie Schol. Mem. 7. pp. 102–181, 1916.)—Describes experiments carried out with a view to ascertaining the effect of the various commercial deoxidisers in rendering steel sound, especially as regards blow-holes. A Tropenas 2-ton converter was used for the experiments, and the oxidising conditions were exaggerated and the metal overblown. The deoxidisers examined were ferro-manganese, ferro-silicon, ferro-carbon-titanium, carbon-free ferro-titanium, and aluminium. The relative density of the ingots obtained was determined by weighing in air and in water, and the results show that Al added in the ladle gives the densest ingots, while the efficacy of the other deoxidisers is in the following order: silicon, Al added in mould, carbon-free ferro-titanium, ferro-manganese, ferro-carbon-titanium. Photographs of the cross-sections of the cropped ingots, taken at the point of cropping, are given, which indicate that Al and Si produce a small pipe but few blow-holes, if any, whereas both titanium alloys and ferro-manganese produce many blow-holes but little if any pipe.

C. O. B.

**341.** *Metallurgy of Cadmium.* **F. Juretzka.** (Metall u. Erz, 12. p. 235, 1915. Translation by O. C. Ralston. Met. and Chem. Eng. 16. pp. 146–148, Feb. 1, 1917.)—Of the chief cadmium ores utilised in Germany, zincblende contains only 0·15 to 1 % Cd and calamine 0·3 to 5 %. Much of this cadmium passes into the flue dust during roasting, and some may be extracted with water as soluble sulphate. The zinc dust may be dissolved in hydrochloric acid. Part of the Cd, and the Pb, remains in the residue: the dissolved Cd is precipitated by zinc dust; but there is much waste in this wet process. As a rule the zinc dust is distilled, when the cadmium deposits in the prolongations of the retorts during the first 1½ hours; the crude cadmium is mixed with 40 % charcoal (or more coke) and redistilled in iron retorts (described), and finally cast in iron moulds. Statistics of production up to 1913 and prices are given, and cost estimates are added.

H. B.

**342.** *Influence of some Elements on the Mechanical Properties of Steel.* **J. E. Stead.** (Iron and Steel Inst., J. 94. pp. 5–99; Disc. and Corres., 100–186, 1916.)—This paper consists largely of a review of previously published work on the influence of carbon, phosphorus, sulphur and manganese, silicon, copper, and tin. In the introduction the mechanical properties, such as max. stress, elastic limit, etc., are defined, and also some of the operations used in thermal treatment, viz. annealing, normalising, and tempering.

The paper is unsuitable for a short abstract, and contains a large amount of information. A bibliography of literature on relations of chemical composition and physical properties of iron and steel is appended. C. O. B.

**343.** *Polymorphic Changes under Pressure of the Univalent Nitrates.* **P. W. Bridgman.** (Am. Acad., Proc. 51. pp. 581–625, April, 1916.)—In this paper the thermodynamic elements involved in the polymorphic changes of a group of closely related univalent nitrates are given over a considerable pressure and temperature range. The apparatus, experimental methods, and modes of computation are identical with those described previously. Particular interest attaches to the group of the univalent nitrates, because of the wide occurrence of polymorphism in this group, the unusual number of polymorphic forms, and their complicated relationships. Here, we should expect, is a particularly favourable field in which to look for new forms, stable only at high pressures, which will supply the gaps at atmospheric pressure. It turns out, however, that there are comparatively few new forms in the range reached here: one new form for ammonium nitrate and two for potassium nitrate. The data are presented in the order of complication of the phase diagrams, and include the coordinates of the transition curves, the change of volume, latent heat and internal energy, and in those cases where the measurements were sufficiently accurate an estimate of the difference of compressbility, thermal expansion, and specific heat of the different modifications. In the discussion of the relations of the various forms it will appear that the three simplest nitrates, those of rubidium, cæsium, and thallium, are much alike in their behaviour under pressure; the nitrates of ammonium and potassium are much less simple in their relations, and silver nitrate is apparently not connected with these at all. Silver nitrate first receives detailed attention. Here pressure was transmitted directly by kerosene, and the possibility of hysteresis was avoided as far as possible by running the pressure back and forth several times over the transition before beginning the measurements. The unique feature of particular interest is the remarkably sudden increase of curvature of the transition line beyond 6000 kg., and this is so great that a third modification was suspected, but could not be detected however. Cæsium nitrate is next described, followed by that of rubidium. Thallium nitrate had to be prepared, and full details are given of the method employed. Potassium and ammonium nitrates are next treated at great length. The following nitrates were examined without result for other forms between 1 and 12,000 kg. at 20° and 200°: $NaNO_3$, $LiNO_3 + Aq$, $Hg_2(NO_3)_2$, $Hg(NO_3)_2$, $Pb(NO_3)_2$, $Al(NO_3)_3$. Sodium, although chemically similar in many respects to potassium and the other alkali metals whose nitrates are polymorphic, is in its crystalline properties so much dissimilar that its salts do not form isomorphic mixtures. From this point of view it is therefore not surprising that no new forms were found. $NaNO_3$ (which is trigonal) does, however, crystallise isomorphously with the high-temperature form (trigonal) of $AgNO_3$, and will crystallise in small percentages isomorphously with the low-temperature form. The author suspects, therefore, that $NaNO_3$ has a second modification, stable at low temperatures at atmospheric pressure, but has not as yet searched for it. Most of the facts described in the paper are collected and exhibited qualitatively in one

diagram which shows the phase diagrams, pressure against temperature, and indicates other data also. The various drawings are made with some exaggeration, so that the direction of curvature of each transition line may be readily noticed. It is found that $AgNO_3$ may be disregarded in any comparative study, as it belongs to a class apart from the five other univalent nitrates. One conclusion drawn is that similarity of phase diagrams is evidence of the most complete similarity of structure, more complete even than the ability to form continuous series of mixed crystals. It is significant that at high pressures the diagrams of all five univalent nitrates tend to the simple type, the disturbing complications being only found at low pressures.
H. H. Ho.

**344.** *Velocity of Polymorphic Changes between Solids.* **P. W. Bridgman.** (Am. Acad., Proc. 52. pp. 57–88, July, 1916.)—In preceding papers the author has presented complete data for a number of polymorphic transitions between solids under high pressures. It is well known, however, that data which may be complete from the point of view of thermodynamics may not be at all complete from other standpoints, and therefore cannot be complete enough to determine the mechanism of a process. In this paper additional data for the reaction velocity from one phase to another are given for many of the substances for which the thermodynamic data have been given in preceding papers. The plan of presentation is as follows. First, is given such description as may be necessary of experimental methods, the method of computation from the data, and the abbreviated graphical method by which an entire curve is represented by a single point. This involves emphasis of two important facts, viz.—that there is a distinct region on both sides of the equilibrium point within which the reaction will not run, and that the reaction velocity varies according to the direction in which it is running, being almost always slower in that direction which is accompanied by rising pressure. The data for all the individual substances for which the data are now at hand are then presented, and, finally, the significance of the data and their suggestions as to a possible mechanism are discussed. Since to every equilibrium point of the preceding papers there may correspond two velocity curves giving the rate of reaction with rising and falling pressure, it was not always found practicable to obtain them, especially if the reaction were a rapid one or accompanied by a small volume-change, so that the data given here are by no means so complete as the equilibrium data. The individual substances studied were: Phosphorus, ammonium sulphocyanide, carbon tetrabromide, urethane, camphor, cæsium nitrate, silver nitrate, ammonium nitrate, carbamide, acetamide, and potassium chlorate. The rate at which one polymorphic modification is transformed into another has been measured by the time rate of change of pressure at constant temperature during the transition. It is probable that all the measurements of this paper have to do essentially with the rate of advance of a single surface separating the two phases. The rate of advance increases rapidly as pressure is displaced from the pressure of equilibrium between the phases. As a rough comparative measure of the speed of the transition, the pressure acceleration of the speed at zero velocity may be used. The acceleration of nearly every transition is not symmetrical with respect to the direction of the transition, but is greater in the direction accompanied by decreasing pressure. The acceleration of the transition and the breadth of the band of indifference (the region on both sides of the equilibrium point within which the transition will not run even when the two phases are in contact) vary with pressure and temperature along the transition curve; the manner of variation is different for different substances. It results from these facts that an equilibrium between polymorphs cannot be due to a balance between two transitions running in opposite directions, as is the case for vaporisation. This implies that in a crystalline solid the velocities of temperature agitation of the molecules cannot be distributed over a wide range of velocities, as is demanded by Maxwell's distribution law for gases or liquids, but must be confined within a restricted range. The boundaries of this range may be more or less sharp. The sharpness of the boundary is an important factor in determining the acceleration of the transition velocity.

H. H. Ho.

**345.** *Polymorphism at High Pressures.* **P. W. Bridgman.** (Am. Acad., Proc. 52. pp. 91–187, July, 1916.)—In this paper complete data (phase diagrams and other thermodynamic results) for polymorphic transitions under high pressures are given for ten new transitions, and incomplete data for five or six others. This brings the total number of polymorphic substances investigated to date to 87, including 84 new phases whose existence was not known before. In addition to those showing polymorphism, 94 other substances are enumerated which have been examined to 12,000 kg. pressure at 20° and 200° without result. The purpose of this paper, beyond the presentation of new data, has been to coordinate the mass of results now obtained so as to examine the entire field. To this end all the substances examined have been collected into various groups, chemical or not, according to the various clues which suggested an examination of them, and part of the discussion is concerned with these possible clues. The discussion also takes up a number of other general considerations connected with polymorphism, and tries to picture what may be the mechanism of a polymorphic change. It must be emphasised, however, that a complete explanation or description of polymorphism from data such as these cannot be given inasmuch as other data particularly of a crystallographic character are needed before the picture is complete. The individual substances examined were: Acetic acid, acetamide, carbamide, camphor, potassium acid sulphate, ammonium acid sulphate, cuprous iodide, ammonium iodide, ammonium bromide, ammonium chloride, the antimony sulphides, double sulphate of zinc and potassium, thallium, ammonium potassium phosphate, and potassium binoxalate.

The author discusses at some length the nature of the various clues. That of chemical similarity is the most obvious, since if one substance shows polymorphism, we may expect others built up on the same chemical scheme also to have polymorphism, and the expectation is highest if the substances differ only by the replacement of one element by another which usually stands to it in the relation of isomorphism. Crystalline form is in consequence an important factor in the matter of chemical replacement, as the chances are much greater for polymorphic similarity in those cases where the known forms belong to the same systems. The existence of mixed crystals suggests the existence of other forms. Salts with water of crystallisation might possibly be expected to show other forms under pressure, since the water molecules are a much less tenacious part of the compound and might be compelled to assume new bonds by the high pressure. Similar reasoning suggests that possibly double salts will assume other forms under pressure. Substances which crystallise in unstable forms from the melt, like a number of organic compounds, would seem to be promising material, because the molecules are known to have the capability of being built up into several arrangements. In the same way, one might hope for polymorphism among those inorganic compounds which are known to exist in several forms as minerals, but whose relationship of monotropy or enantiotropy is not known. Also where the transitions are above 200° at atmospheric pressure, it might be expected that pressure will bring them within the region of this investigation. Tammann has suggested that according to his theory there is a particularly good chance of polymorphism among those substances whose melts are associated, e.g. most organic acids are associated when liquid and a number of these substances have been investigated.

Sixteen pages are devoted to the classification of substances into chemically related groups. A compact summary of the nature of the effects for all polymorphic transitions examined is given in two comprehensive diagrams, and these bring out the fact that mere chemical similarity is not sufficient to ensure similarity of phase diagrams. The latter, however, involves a much more far-reaching correspondence of mechanism than similarity of chemical behaviour, for it means not only an identity of structure so complete that similarly arranged edifices are possible, but also means that the fields of force surrounding the elements are so similar that corresponding edifices are stable. The author points out that to class a substance as polymorphic if it has more than one modification, stable or not, has no well-defined significance, and he confines the use of the word "polymorphic" to those substances with two or more phases which are capable of reversible transitions. It seems as a general average that about one out of three substances is polymorphic. Following this discussion comes an examination of the relative frequency of occurrence of the different crystalline systems. The general thermodynamic aspects of the phase diagrams receive a most exhaustive review, and an inquiry is made as to whether the theory of solids derived from the quantum hypothesis has any restrictions to impose on the shape of the transition lines. Brief mention is made of Smits' recent theory of polymorphism, which is that any substance showing polymorphism forms at least two different kinds of molecules, which are present in both phases but in different proportions, the ratio between the two kinds in a single phase varying continuously with the temperature. Substances like benzol are examined in which the transition has no latent heat but the internal energy of the phase of smaller volume is the greater, these constituting puzzles of polymorphic change. The bewildering complexity shown by various polymorphic transitions throws light on a group of phenomena of another kind, namely: In a previous investigation it appeared that under the more moderate pressures all liquids tended to a more or less common type of behaviour, but that at higher pressures the most varied abnormalities made their appearance, each liquid behaving in its own characteristic way. These abnormalities seem to show an approach to some kind of order brought about when the molecules are squeezed closer together by high pressure. As pressure and temperature shift, the predominating type of order in the relation of the molecules may change also, and there occur the varied effects similar to those when the arrangement of the atoms is altered as it is in a polymorphic transition. It seems natural to assume that the same sort of considerations and mechanism which will some day be discovered to account for polymorphic changes will also account for the complicated phenomena in liquids at high pressures. As a summary the author concludes that there is no simple type toward which all polymorphic diagrams tend at high pressures, nor are there a few common types. The complication is very great; probably no solid transitions of any type whatever exist, except those involving a critical point. It is suggested that in order to explain these complicated phenomena the effect of the shape of the atoms is the next factor to be considered, and it is shown in detail by considering several artificial examples that assemblages of units of definite shape provided with localised centres of force are capable of exhibiting the variety of behaviour which actual polymorphic substances show. The paper brings to a close this series of investigations, owing to the fact that most of the substances which now suggest themselves for examination are unobtainable for the present, and also that the number of substances investigated seems large enough to warrant a theoretical examination of the entire field. H. H. Ho.

**346.** *Impact-ionisation of Gases by Heat Motion.* **F. v. Hauer.** (Phys. Zeits. 17. pp. 583–585, Dec. 1, 1916.)—Numerous experimental researches have shown that there always exists in a closed vessel containing gas or vapour a certain amount of residual ionisation, represented by a production of ions at the rate of about 10 per sec. After eliminating the ionisation due to radio-active contamination, this residual ionisation in general may consist of ionisation ascribed to (1) the radio-active radiations from the walls of the vessel, (2) the penetrating radiation of the earth and the atmosphere, and (3) impact ionisation due to the "heat"-motion of the molecules of the gas in the vessel. In the last case we get a condition of dissociation of atoms into ions, similar to that usually associated with metallic substances in the solid state.

Employing the Maxwellian equations for gases, the author obtains an expression for the upper limit of the number of ions per cm.$^3$ per sec. produced by the heat motion of the gas molecules at any temperature. Thus, for hydrogen at 300° abs., this quantity is equal to $3 \times 10^{-188}$, *i.e.* practically zero. Hence, at ordinary room temperatures no part of the "residual ionisation" observed in closed vessels can be ascribed to this cause. As the temperature increases above 2000° abs. the rate of production of ions due to heat motion rapidly increases. A. B. W.

**347.** *Counter Electromotive Force in the Aluminium Rectifier.* **A. L. Fitch.** (Phys. Rev. 9. pp. 15–23, Jan., 1917.)—Experiments have been made with a cell composed of a lead plate and an Al wire immersed in saturated sodium phosphate solution, a potentiometer method being devised for the measurement of the counter e.m.f. The results obtained show that any method of experimenting in which an appreciable period of time must elapse during the taking of data—the cell being on closed circuit with the battery at least a part of this time—will introduce serious errors owing to the changes occurring in the cell itself. No previous attempt seems to have been made to explain the action of the cell on the theory that the action is due to a double dielectric, one part of which changes with the time of open circuit and the other with the time of closed circuit, but the author now shows that such a theory is plausible, and fully explains all the cases investigated. The cell does not attain a steady state after a short time of closed circuit, and the single dielectric theory seems insufficient.

The theory suggested leads to the conclusion that any electrolyte which liberates oxygen on electrolysis may be used in the rectifier. It shows, further, that other metals than Al should be available as anodes, since it only requires that the metal shall form a compound with the liberated oxygen, and that this compound shall have a somewhat high resistance. T. H. P.